TWO-DIMENSIONAL HYDRAULIC MODELING OF THE UPPER SACRAMENTO RIVER, RM 194.0 TO RM 202.0 INCLUDING RIPARIAN RESTORATION, SETBACK LEVEE, AND EAST LEVEE REMOVAL. GLENN AND BUTTE COUNTIES, CALIFORNIA

May 31, 2002

Prepared for:

The Nature Conservancy
CALIFORNIA

500 Main Street, Suite B
Chico, California 95928

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Table Of Contents

Table of Figures

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by
The Nature Conservancy

Description of Modeling Approach, Assumptions, and Methods

The Nature Conservancy (TNC), the California Department of Fish and Game (DFG), the U.S. Fish and Wildlife Service (USFWS), and the Wildlife Conservation Board (WCB) were awarded CALFED funds in 1997 for the acquisition and start-up stewardship, including preparation of long-term management and monitoring plans, on lands acquired within the Sacramento River Conservation Area (as defined by SB 1086). A steering committee was formed among the award recipients to make consensus decisions regarding implementation of the project. Stakeholder input was sought to identify information needs (e.g. public use and access) to be addressed as part of the management planning process for the acquired lands. Hydraulic modeling was identified as a priority to evaluate the potential third party impacts of large-scale conservation strategies in the context of other uses of the floodplain. Ayres Associates was hired to conduct the modeling. TNC's role was to develop and provide Ayres Associates with the data input required for the modeling exercise.

Model input supplied by TNC included land use data, a setback levee alignment, and removal of small private levees. Cultivated restoration strategies, or land use data, were developed with a science-based planning process utilizing long-term monitoring plots first established in 1990. This process is described in more detail in (TNC 2001). In summary, TNC science staff evaluated soil and vegetation conditions at long-term monitoring plots and categorized these conditions into broadly defined vegetation community types (forest, savanna, grassland). Preliminary analysis of soil core data at long-term plots suggested relationships between soil characteristics and the vegetation community type capable of surviving on a site. These relationships were used to develop the most conservative *potential vegetation community type*. This potential vegetation community type is defined as the most dense riparian vegetation type deemed capable of surviving on all publicly owned parcels in the Hamilton City area. The approach was to develop the most cumulative and conservative impact due to flooding characteristics as a result of conservation strategies.

TNC also supplied Ayres Associates with a setback levee alignment, which was developed by stakeholders in the Hamilton City area. All TNC owned or managed parcels were made "available" to the design of a stakeholder preferred levee alignment. The Hamilton City Community Services District played a lead role in coordinating stakeholders' input, which defined the levee alignment that was modeled. TNC will continue to be a participant of the Hamilton City Workgroup as that forum facilitates the discussion of activities in the Hamilton City area.

Removal of private levees was also evaluated for the dual goals of flood damage reduction and ecosystem restoration. Ayres Associates suggested which private levees on the east bank of the river, on the USFWS Pine Creek Unit that could be removed in the modeling effort to meet these dual goals.

The following points summarize the approaches and assumptions used in this modeling exercise to ensure the most accurate results.

- Data used to formulate large-scale planning relationships was developed over a 10-year period at 106 monitoring plots.
- Local landowners and stakeholders were consulted numerous times, during the model calibration process, to increase the accuracy of the model results.
- Local landowners were also consulted and agreed with the designation of potential vegetation communities based on past personal observation while growing up in the area.
- If a location's site characteristics were in question we defaulted to include the most dense *potential riparian vegetation community* in order to generate the most floodplain roughness, and thus the most conservative estimate of impact.
- Levee strategies were developed with the goal of directly benefiting neighboring lands by opening public lands to flooding, thereby reducing flood pressure on the neighboring lands.

This modeling exercise is part of a comprehensive process to develop tools that help inform management decisions for the Sacramento River floodplain. For example, this modeling estimates flood damage reduction in the Rt. 32 area, resulting from the various conservation strategies. The combined benefits of these strategies equal approximately 1 foot of decrease in flood stage in the Rt. 32 area compared to existing conditions during an approximate 15 year return interval flood event. Other local increases and decreases in both flood stage and velocity result throughout the modeled area. The continued development of science-based approaches will assist all stakeholders in developing informed strategies that address and minimize potential third party impacts. The ability to analyze 10 years of data to formulate our approach and assumptions in this modeling exercise provides us with a high degree of confidence in the results. Other exercises using this model will likely generate other degrees of confidence in their results based on the assumptions and data input used in those exercises.

1 Introduction

1.1 General Background

The Sacramento River flows south from Shasta Dam, through the Sacramento Valley and into San Pablo Bay. Of the 300+ miles of river, the lower 176 miles are bounded by project levees on either side. Outside of the project levees, the hydraulics of the upper Sacramento River system become more complex due to water exchange between the main channel and the overbank floodplains. The flow is constrained by natural landforms and an unconnected series of local and private levees. Throughout this upper reach, the surrounding land typically consists of cultivated fields, orchards, riparian areas, and grassland.

The hydraulic modeling performed for this project focuses on a reach of the Sacramento River from river mile (RM) 194 to RM 202 as shown in **Figure 1**. The Nature Conservancy (TNC) has purchased several parcels of land throughout this reach and has proposed land use changes, including riparian restoration. **Figure 2** is a plot showing public and private ownership along the project site. Along with riparian restoration, TNC has also proposed options for a setback levee, and the removal of some private levees located on the east side of this reach. These proposed alternatives will be discussed in further detail later in this report. This project was initiated by TNC to determine the hydraulic effect these changes would have on water surface elevation, flow velocity and flow patterns. Due to the complex nature of the river and floodplain, two-dimensional hydraulic modeling was chosen as the preferred tool for this analysis.

1.2 Purpose and Scope of Project

The purpose of this project was to develop a two-dimensional hydraulic model of the eight mile reach of the Sacramento River between RM 194 and RM 202. The model would extend upstream from a previous two-dimensional model encompassing RM 174 – 194, developed for the U.S. Army Corps of Engineers (USACE) (Ayres Associates, 1997). Once developed and calibrated, the upstream model was used to analyze the hydraulic impacts of proposed alternatives along the Sacramento River and floodplains. This report includes the following tasks:

- *Develop and Calibrate a Hydraulic Model to the 1995 Flood Event* – This task called for the creation of a two-dimensional model of eight miles of the Sacramento River from RM 194 to RM 202. The model was calibrated to the flood flow of January 1995 using high water marks staked for that event, and reflected topographic and river configuration conditions as they existed in January 1995.

- *Develop an Existing Conditions Hydraulic Model* – This hydraulic model simulates the 1995 flood flow using post-January 1995 topography, river configuration and land use.

- *Proposed Alternatives Hydraulic Model Runs* – These hydraulic simulations will analyze the effects of the potential land use changes, setback levee alignment and the removal of east levees, on parcels in conservation ownership in this reach.

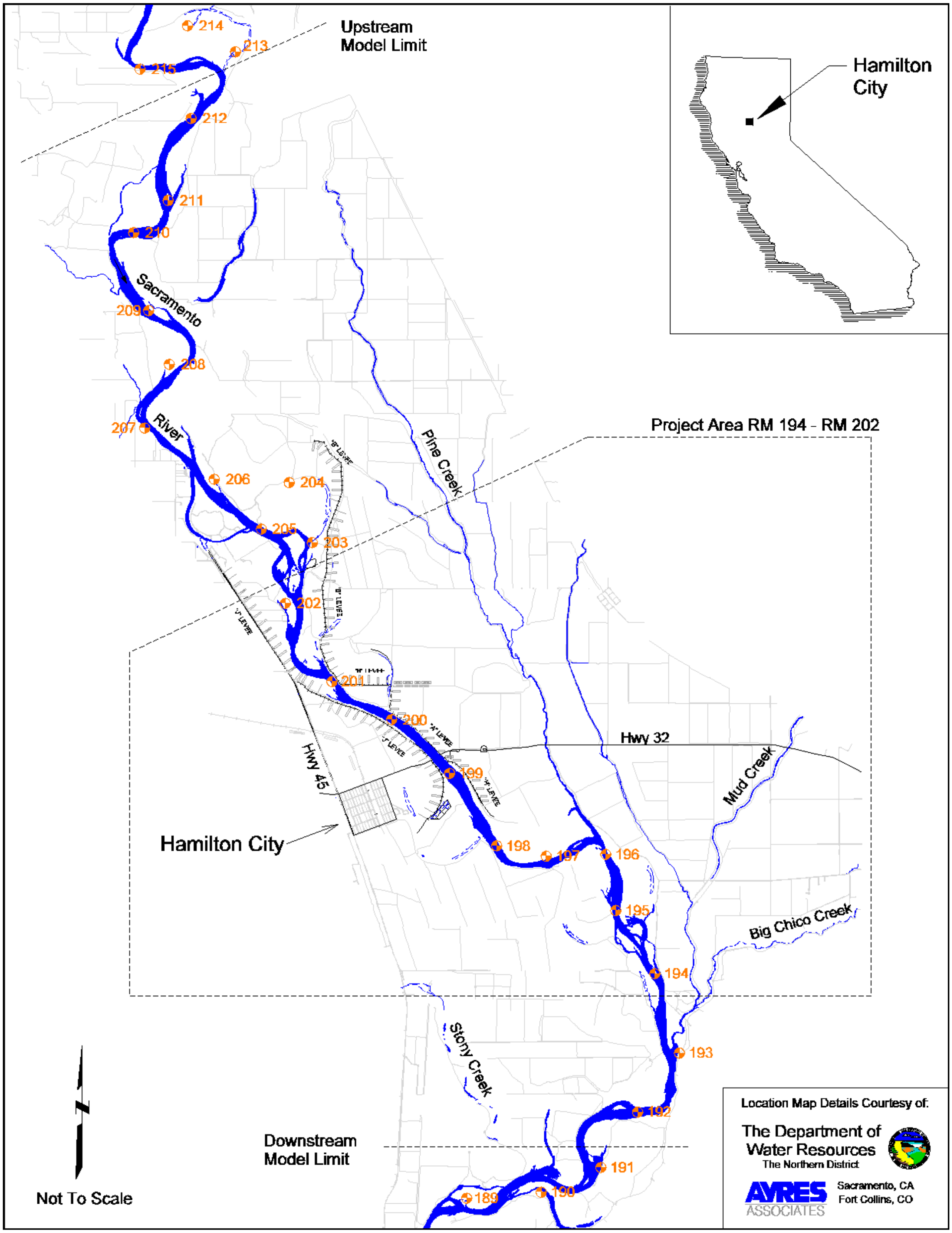


Figure 1. Location Map – Project Site Delineation

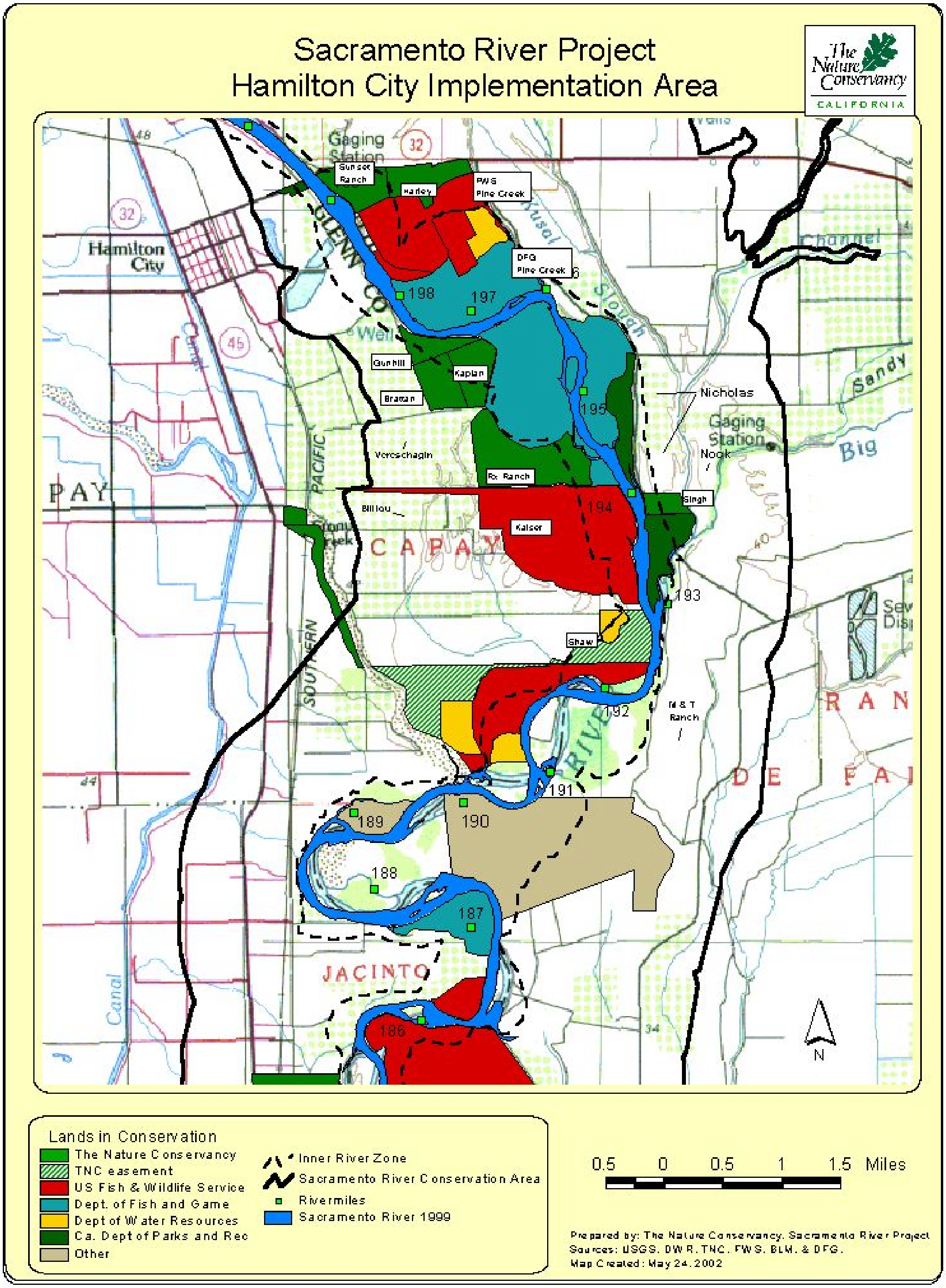


Figure 2. Land Ownership within Project Area

1.3 Acknowledgements

This analysis was authorized by The Nature Conservancy (TNC) through the Sacramento River Projects office in Chico, California. The point of contact for TNC is Mr. Michael Roberts. The hydraulic modeling was conducted by the Sacramento office of Ayres Associates under the direction of Mr. Thomas W. Smith, P.E., G.E.

2. Discussion of Hydraulic Model Runs

2.1 Existing Conditions Hydraulic Model

The existing conditions hydraulic model represents the land use and river configuration that existed following the 1995 flood events. This model uses the topographic and hydrographic mapping data developed by the Corps of Engineering following that event. This run will serve as a baseline for comparison with land use, water surface elevation, and velocity. The land use configuration is shown in **Figure 8** in the appendix.

2.2 Riparian Restoration Hydraulic Model

The riparian restoration model incorporates potential land use changes within conservation ownership parcels. The new land use configuration was provided to Ayres Associates by TNC and is shown in **Figure 11** in the appendix. The primary areas for land use conversion included the lands on the east side of the river downstream of Highway 32 and along both sides of the river from RM 194 to 197. These areas of restoration are shown in **Figure 2** and are referred to as the Kaiser Unit, the Fish and Wildlife Service (FWS) Pine Creek Unit, the Department of Fish and Game (DFG) Pine Creek Unit, and the RX Ranch Unit. These potential changes are not detailed restoration design, but a reflection of the densest riparian communities capable of surviving on these sites. The riparian community designations for this run are based on a correlation between vegetation density and site characteristics, including topography and soil types.

2.3 Hamilton City Setback Levee Hydraulic Model

The setback levee model represents a realignment of the west bank levee along the river as shown in **Figure 3**. The levee is generally setback around 1000 ft. from the existing levee upstream of RM 195. However, downstream of RM 195, the levee moves closer to the river. This alignment is based on the local stakeholder's (representing the Hamilton City area) preference. The new levee cuts through an existing oxbow, near RM 198, to keep a wastewater facility (located in the northwest portion of the oxbow) out of the floodplain. This run also includes the riparian restoration conditions described above.

2.4 East Overbank Levee Removal Hydraulic Model

The east levee removal model removes three small private levees on the east overbank floodplain, near RM 198. These levees are shown on **Figure 4**. The land where these levees are located has been bought by TNC and they wished to consider the removal of these levees. The land use at the levee locations will be changed to reflect the surrounding land uses. The land use plot for this run is shown on **Figure 12**. This run also includes the riparian restoration and the setback levee conditions described above.

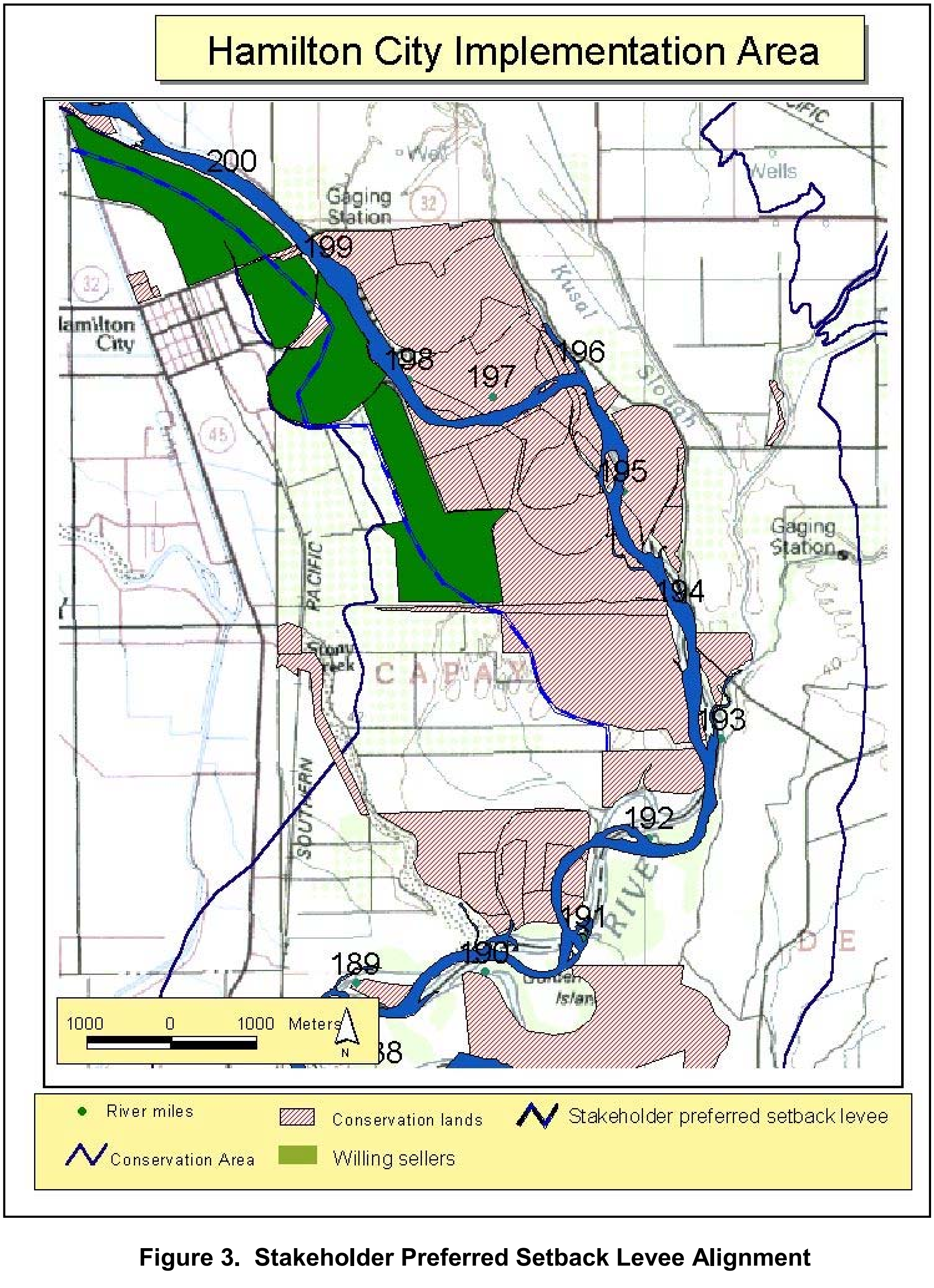


Figure 3. Stakeholder Preferred Setback Levee Alignment

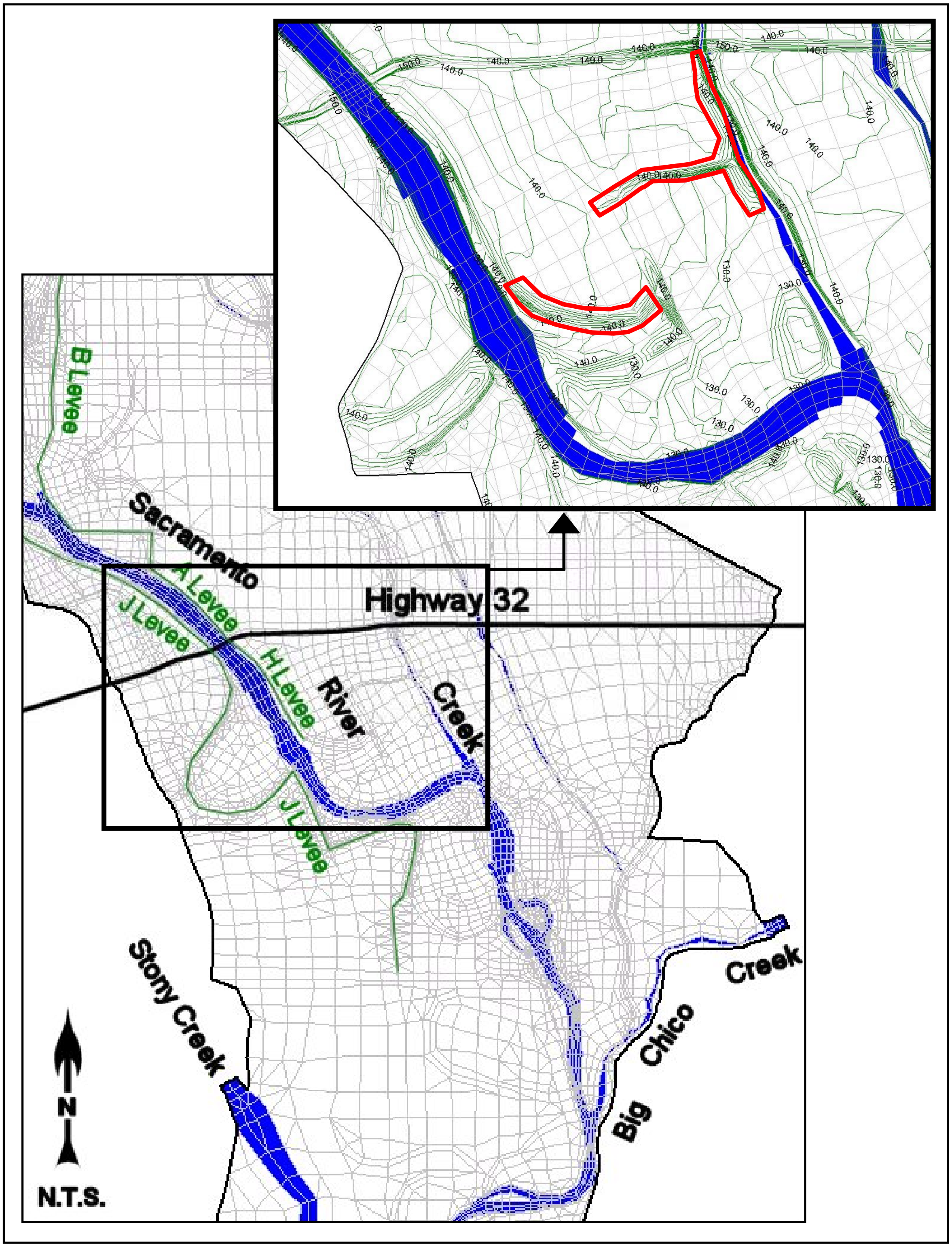


Figure 4. Location of East Overbank Levee Removal

3. Hydraulic Modeling

3.1 General

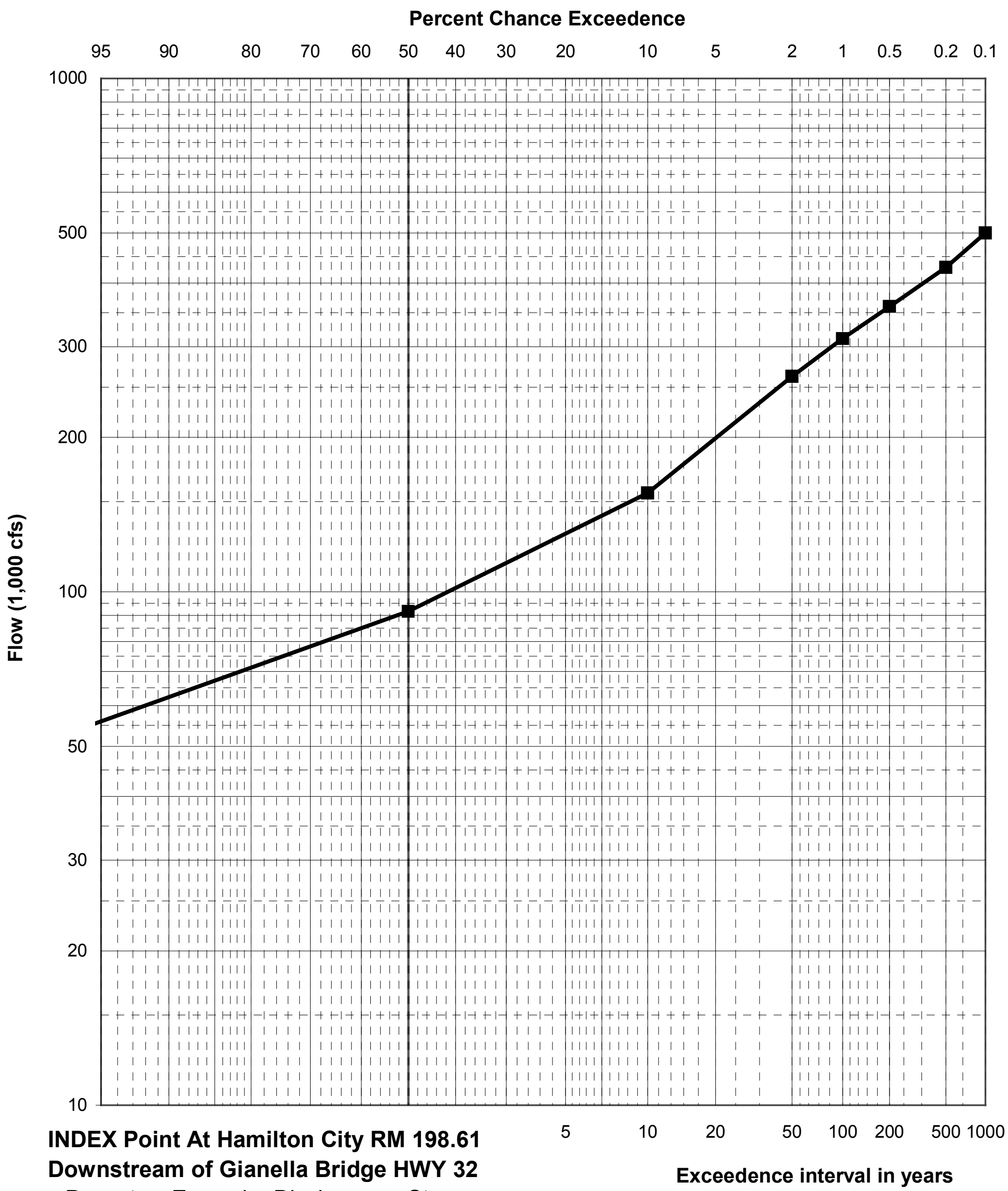
A previously developed existing two-dimensional model of the Sacramento River from RM 174 to RM 194 is located immediately downstream of the reach of interest in this report. This lower model was developed for the USACE in 1997 to better understand the hydraulic characteristics of the Sacramento River as it interacts with the adjacent Butte Basin floodplain. Bathymetric and photogrametric data were collected in 1995 and used as the topographic basis of this previous modeling effort. The lower model was run using the peak flow from the 1995 flood event that occurred in January of that year and was calibrated using high water data collected on the 10^{th} and 11^{th} of the same month. This run provided boundary conditions for the current model, since it is based on the same topographic data and simulates the same flood event of 1995.

The 1995 peak flow of 170,000 cfs is estimated to be approximately a 15-year runoff event. This flow was an observed event in 1995, and is based upon the hydrology developed by the US Army Corps of Engineers for their ongoing Comprehensive Study. The use of any other hydrology may produce a different designated event. **Figure 5** shows the frequency-discharge plot for this reach of the Sacramento River based on flow records at the Hamilton City stream gage (Corps of Engineers, 2001).

3.2 Model Development

The two-dimensional model for this project was developed to quantify the effects that proposed land use changes and altered levee locations would have on water surface elevation, velocity, and flow patterns within the floodway. The project site is located between RM 194 and RM 202, while the model itself extends from RM 191 to RM 213. Extending the model limits unnatural influences of the boundary conditions and provides topographic definition to characterize the flow distribution into the project site. Three miles of overlap exist between the downstream end of this model and the upstream end of the lower model.

Geometric definition of the project reach is given in the form of a finite element network of triangular and quadrilateral elements as shown in **Figure 6**. The corner nodes of each element represent points in space (X, Y,Z) defining the topography of the project reach. These nodes were laid out using topographic mapping and aerial photography as a reference for element size and orientation. Nodes were also added at spot locations to define breaklines, structures, or other significant changes in topography. Elevation values were assigned to the nodes using a digital terrain model of the river reach. The existing model reflects the river configuration as it existed after the 1995 flood events, based upon mapping developed for the USACE in August of 1995.



INDEX Point At Hamilton City RM 198.61
Downstream of Gianella Bridge HWY 32

Pecent Exceed.	Exceed. Years	Discharge c.f.s.	Stage feet NGVD
0.10	1,000	500,000	154.32
0.20	500	428,407	153.01
0.50	200	359,872	151.64
1.00	100	311,263	150.52
2.00	50	263,022	149.31
10.00	10	155,841	146.36
50.00	2	91,668	141.91
99.99	1	30,000	131.98

SACRAMENTO-SAN JOAQUIN COMPREHENSIVE STUDY
SACRAMENTO RIVER BASIN, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
SACRAMENTO RIVER AT RM 198.61
HEC-RAS Model Results

U.S ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

1-Sep-00

Figure 5. Frequency-Discharge Plot for Sacramento River at Hamilton City

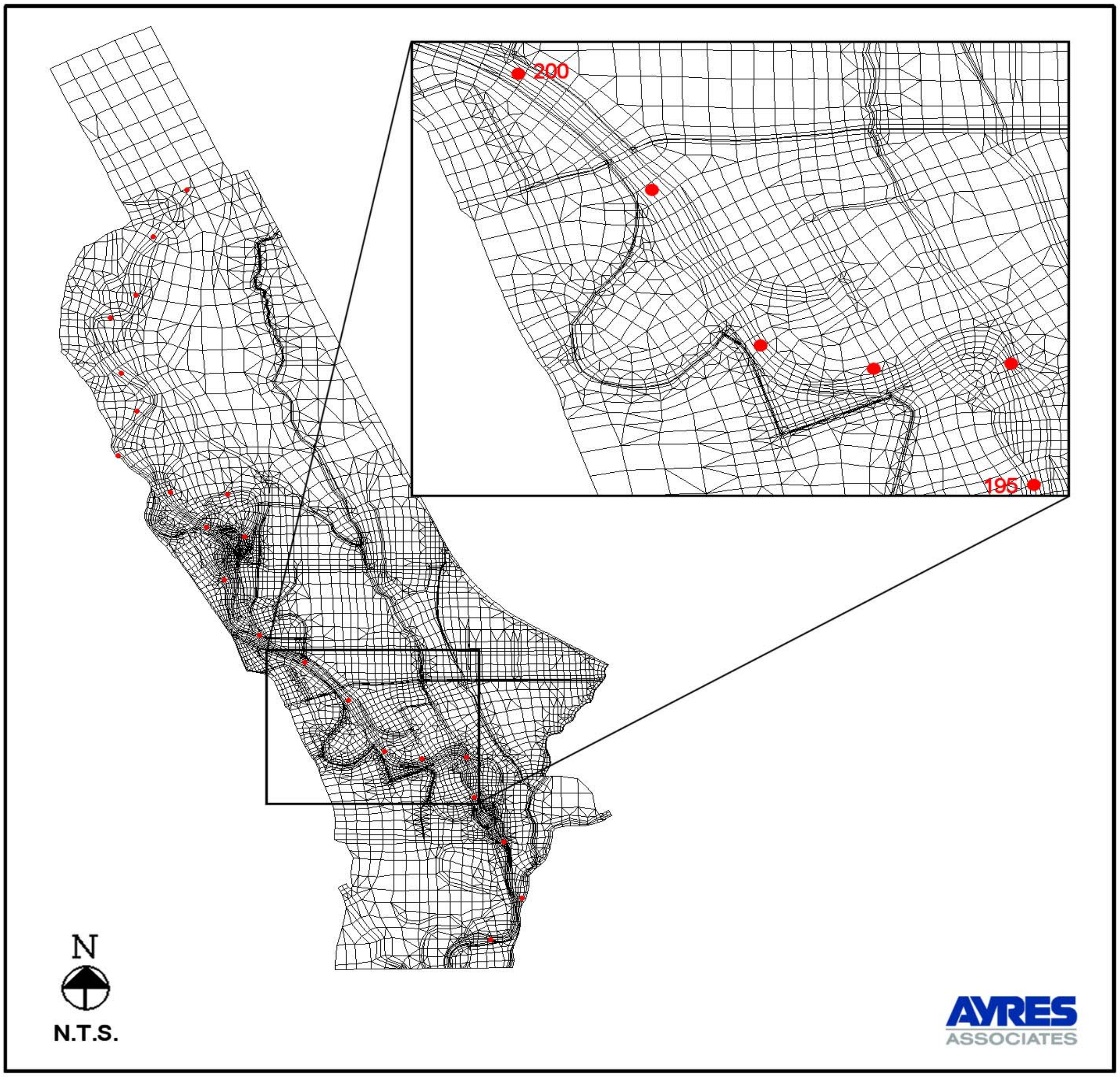


Figure 6. Plan View of the Finite Element Mesh

In the river reach, material types within each element were categorized based on land use and roughness characteristics (dense vegetation, grassland, sandbars, etc.). The material types were assigned to each of the elements in the finite element mesh using aerial photography from the 1995 mapping effort conducted by the USACE and the 1997 Sacramento River Aerial Atlas developed by the Department of Water Resources, Northern District (DWR, 1997). A field visit was also made to confirm land usage. For each material type, a Manning's roughness coefficient (n value) was assigned to represent roughness types. These values were determined primarily from the previous modeling effort, and originally were derived using standard engineering protocols and references. Material types and corresponding Manning's n values used in the model are listed in **Table 1**. **Figures 10 – 13**, in the **Appendix** further describe the layout for each material type for the existing, proposed restoration conditions, proposed setback levee conditions, and the proposed east levee removal conditions, respectively.

Table 1.
Manning's Roughness Coefficients (n Values)

Element Type	Description	Manning's n Value
1	Main channel	0.035
2	Heavy riparian vegetation	0.160
3	Orchards	0.150
4	Cultivated field (fallow)	0.035
5	Bare sand bars	0.040
6	Stony Creek bed	0.040
7	Pasture/Grassland	0.035
8	Savannah	0.050

3.3 Model Calibration

Once the two-dimensional hydraulic model was assembled, it was calibrated against measured high water marks from the January 1995 flood event surveyed by U.S Geological Service (USGS) to check the accuracy. The USGS data used for calibration from this reach of the river is shown in **Table 2**.

Table 2.
High Water Marks (HWM) Surveyed During the 1995 Flood Event.

River Mile	Location	Date Staked	HWM Elevation (ft, NGVD)
208.2	Zuppan Ranch	Jan. 10-11, 1995	163.6
206.3	Spatta	Jan. 10-11, 1995	159.6
203.5	Wilson Landing	Jan. 10-11, 1995	158.3
202.3	Peterson Ranch North End	Jan. 10-11, 1995	156.8
201.8	McIntosh Landing	Jan. 10-11, 1995	156.5
201.2	End Levee Right Bank	Jan. 10-11, 1995	155.3
201.1	Peterson Ranch Pump	Jan. 10-11, 1995	155.3
200.9	Holly Sugar Pumping Plant	Jan. 10-11, 1995	153.6
200.8	HC (X-8)	Jan. 10-11, 1995	153.4
199.5	HC (X-6) Left Bank	Jan. 10-11, 1995	148.5
199.5	HC (X-6) Right Bank	Jan. 10-11, 1995	148.6
199.3	State Hwy. 32 Bridge, Upstream	Jan. 10-11, 1995	148.0
196.1	Scotty's Landing	Jan. 10-11, 1995	141.4
193.0	Big Chico Creek Confluence	Jan. 10-11, 1995	135.2
192.7	Chico Sewer Outfall	Jan. 10-11, 1995	133.6

The peak flow data used for calibrating this model was obtained from the USGS. This same data was used to calibrate the lower model of the Sacramento River and the Butte Basin. The peak flow from the Colusa gage was recorded as 195,000 cfs, where 170,000 cfs was contributed from the Sacramento River, 15,000 cfs from Stony Creek, and 10,000 cfs from Big Chico Creek (Ayres Associates, 1997). The flow entering the floodway from Pine Creek was not reflected in the model due to insufficient data and its relatively minor contribution to the total flow.

Boundary conditions for the model reflect the river conditions in early January 1995, prior to the flood event. The water surface elevation assigned to the downstream end of the model was 30.5 feet. This value was taken from the results of the lower reach model (Ayres Associates, 1997).

Other sources of information were also referenced for model calibration. Mike Bilou, a local landowner, provided local levee elevation data, oblique aerial photography, and maps of his property depicting the extent of the inundated area at the time of the modeled flood event. In addition, a number of public meetings were held, involving stakeholders from Glenn and Butte counties, to offer land owners and managing entities (e.g. Sacramento River Reclamation District) familiar with the area a chance to review preliminary model output. Comments were incorporated to increase the accuracy of the model calibration phase.

During the calibration process, some refinements were necessary to the topographic definition of the model within the project reach. Modifications were made in two areas:

1. Local levee elevations (A, B, H, and J levees), see **Figure 7**
2. River configuration near RM 201-203

During the initial calibration run, the model appeared to be underestimating the water surface elevation in comparison to the surveyed high water marks, most noticeably between RM 201 and 204. During this event, the J levee began overtopping downstream of RM 201 and was subsequently sandbagged to prevent continued overtopping and failure. In the model, water overtopped the J levee prematurely, preventing the water surface elevation from reaching the measured elevation.

In order to resolve this apparent discrepancy, additional survey data were obtained to verify the levee elevations in this location. DWR, Northern District provided top of levee profiles surveyed in 1996 and 1997, and Ayres Associates field surveyed selected points on the levee in August 2001 as a further check. **Figure 8** compares these profiles along with the surveyed high water marks. The field surveyed data (August 2001) compared well with the DWR data except for the area that had been repaired since the DWR survey. Based on the above comparison, the DWR levee elevations were used in the final calibrated model run for the J, A, B, and H levees.

With the revised levee elevations, the model continued to underestimate the water surface elevation near RM 201. Our next step was to determine if the channel configuration had changed substantially during this event. In reviewing aerial photographs dated July 1991, it was noted that the river channel in this area was substantially smaller than the mapped configuration that was surveyed after the 1995 high flow. Using the 1991 aerial photographs as a guide, the river configuration through this reach was modified to estimate the pre-flood configuration. This final modification provided reasonable results for the calibration run and a comparison of the results from each run is shown in **Figure 9**.

Table 3 compares the calibration model water surface elevations to the surveyed high water marks. The water surface elevations were generated from the model based on DWR's 1996/1997 levee profile survey and an estimated river configuration before the high flows of January 1995.

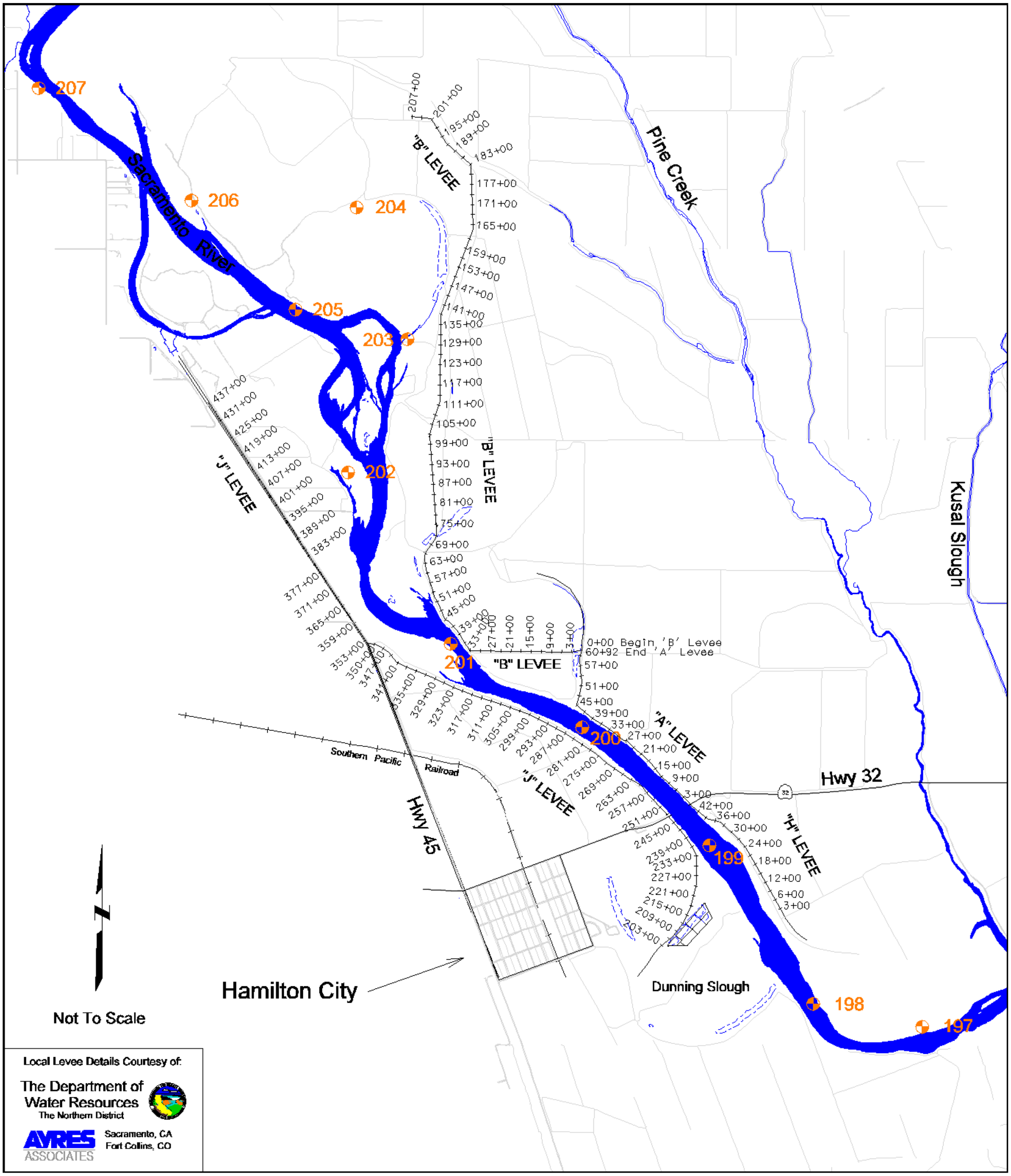


Figure 7. Local Levee Configuration and Stationing

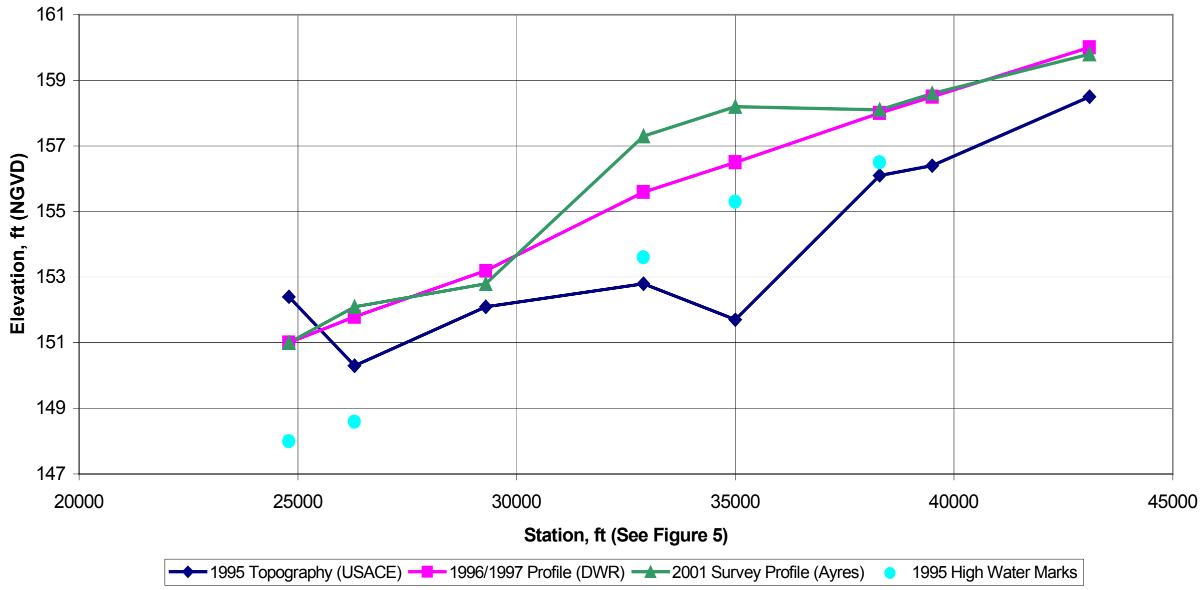


Figure 8. J-Levee Profiles

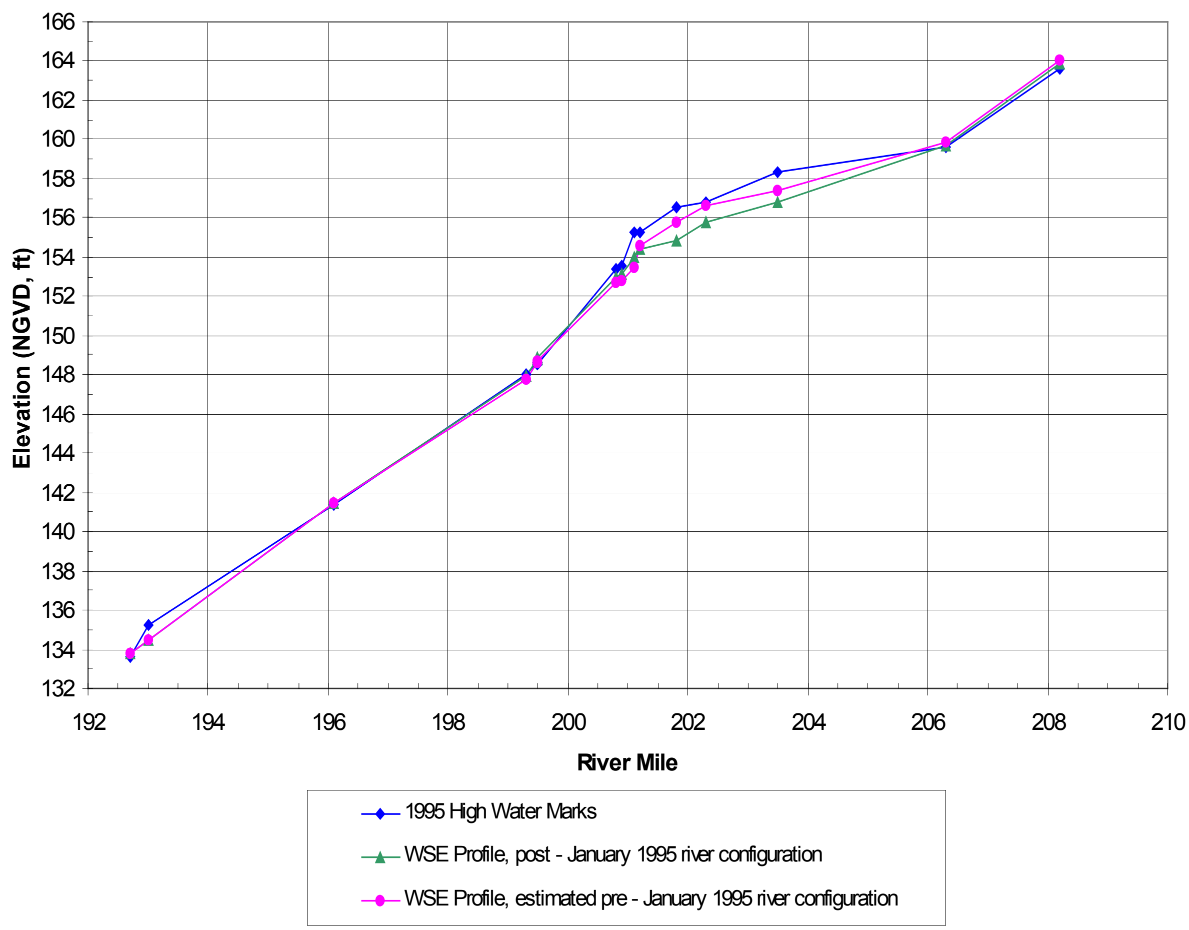


Figure 9. Modeled Water Surface Profiles and Surveyed High Water Marks

Table 3. Comparison of the Predicted Water Surface Elevations From the Model with the Surveyed High Water Marks for the Calibration Run.

RM	Location	Surveyed HWM Elevation (ft, NGVD)	Calibration Water Surface Elevation (ft, NGVD)	Difference (ft)
208.2	Zuppan Ranch	163.6	164.0	+0.4
206.3	Spatta	159.6	159.9	+0.3
203.5	Wilson Landing Road	158.3	157.4	-0.9
202.3	Peterson Ranch North End	156.8	156.6	-0.2
201.8	McIntosh Landing	156.5	155.8	-0.7
201.2	End Levee Right Bank	155.3	154.6	-0.7
201.1	Peterson Ranch Pump	155.3	153.5	-1.8
200.9	Holly Sugar Pumping Plant	153.6	152.8	-0.8
200.8	HC (X-8)	153.4	152.7	-0.7
199.5	HC (X-6) Left Bank	148.5	148.7	+0.2
199.5	HC (X-6) Right Bank	148.6	148.6	0.0
199.3	State Hwy. 32 Bridge, Upstream	148.0	147.8	-0.2
196.1	Scotty's Landing	141.4	141.5	+0.1
193.0	Big Chico Creek Confluence	135.2	134.5	-0.7
192.7	Chico Sewer Outfall	133.6	133.8	+0.2

Based on our professional judgement and experience with previous hydraulic models on the Sacramento River, the overall results show acceptable agreement between the model and the surveyed values. Readings near the far upstream and downstream ends are within 0.5 feet. Not all surveyed points fall within an acceptable range of accuracy. This discrepancy is most likely due to a combination of two factors. First, the exact locations of the surveyed high water marks were difficult to determine based upon the available descriptions and may have reflected local hydraulic conditions not included in the model. Second, the river configuration had changed somewhat through this flood event, causing difficulty in recreating the same local topographic and hydraulic conditions.

3.4 Existing Conditions Hydraulic Model

After calibration to the 1995 peak flow, based on river configuration and land use conditions during the flood event, the model was altered for the existing river configuration and base line land use conditions as they existed after the flood event. Post-flood river conditions were modeled in the existing conditions run. The 1995 bathymetric and overbank topography was used for the river configuration layout. Land use was taken from the 1995 and 1997 aerial photographs (land use did not change significantly during these years) and verified by field inspection to best represent conditions after the 1995 flood event. The modeled land use categories and areas are shown on **Figure 10**.

3.5 Riparian Restoration Hydraulic Model

This hydraulic model uses the same geometry configuration as the existing conditions model. The land use incorporates the potential riparian restoration changes within conservation ownership parcels as provided by TNC. The primary areas for land use conversion include the Kaiser Unit, FWS Pine Creek Unit, DFG Pine Creek Unit, and the RX Ranch Unit. The land uses for this run are shown in **Figure 11** and were incorporated into the hydraulic model.

3.6 Hamilton City Setback Levee Hydraulic Model

This hydraulic model uses the same river configuration as the existing conditions model. A new setback levee on the west side is incorporated into this model as shown in Figure 3. The setback levee provides a wider floodplain from RM 195 – 198 and RM 199 – 201, however the new levee decreases the floodplain width from RM 193 – 195. The land use changes made in the riparian restoration model are also used in this model. The land use conditions used in this run are shown in **Figure 12**.

3.7 Left Overbank Levee Removal Hydraulic Model

This hydraulic model removes sections of three private levees, located on the east side of the river, near RM 198. The new ground elevation is modeled at the level of the surrounding fields. This model .also uses the river configuration from the existing conditions run and the land use from the riparian restoration run . The setback levee configuration is also incorporated into this model. The land use for this model run is shown in **Figure 13**.

4. Discussion of Modeling Results

4.1 Existing Conditions Hydraulic Model

The results of the existing conditions run were used as a baseline to compare changes in velocity, water surface elevation, and freeboard. The velocity contours and vectors show some spots of high velocity in the channel, near RM 194 and 197, and relatively slow velocity in the over banks, as shown in **Figure 14**. The water depths for this run are shown in **Figure 21**.

In several of the figures a region of the map is outlined and referenced as a backwater region. This region was not included in the original model because it is not effective in terms of hydraulic conveyance. The region is located in the Big Chico Creek basin where the proposed projects were not expected to have any effect. After finding significant water surface impacts in this region, results needed to be interpreted using topographic mapping. Rerunning the hydraulic model was not necessary given that the region is not a significant flow path during the modeled event, but a backwater storage area.

4.2 Riparian Restoration Hydraulic Model

The resulting velocity contours and flow vectors for the riparian restoration conditions model are shown in **Figure 15**. The velocity differential plot, comparing the existing velocity to the restoration velocity, is shown in **Figure 18**, and the water surface elevation differential, comparing how the water surface changed from existing to restoration, is shown in **Figure 24**. The water depth for the restoration conditions run is indiscernible from the existing conditions plot (**Figure 21**) at the given scale. As shown in these figures, the potential restoration scenario does have some effect on both water depths and flow velocity within the study area.

With the exception of a few small areas, most changes in velocity are within one foot per second. Comparing the areas where velocities have increased (**Figure 18**) with the velocity contours for the restoration condition (**Figure 15**), the maximum velocities in these areas are less than 5 feet per second which is considered to be the upper limit for non-erosive velocities on well vegetated soils. The change in velocity can be directly attributed to the change in density of the proposed vegetation. Where an area was converted from orchard to grassland, the velocity plot shows an increase and conversely where the vegetation density was increased to riparian forest, the velocity plot shows a decrease.

Channel and floodplain deposition, resulting from the proposed restoration, may be of concern to some stakeholders. There are two locations where expected decreases in velocity may cause deposition. The first location is in the Sacramento River upstream of RM 194, where the most significant decreases is from 7.6 feet per second in the existing model to 6.3 feet per second in the restoration model. The decrease makes the velocity similar to that if the upstream supply reach (RM 195 – 196), and therefore, significant deposition due to the restoration is not expected. The second location is along the eastern edge of the Kaiser Unit (see **Figure 2**), where water leaves the Sacramento River into the right overbank downstream of RM 195. The velocities decrease by 1 to 3 feet per second in the floodplain due to the restoration. The existing velocities are sufficient to transport fine sediment flowing out of the river. This decrease may reduce the existing sediment transport capacity.

The water surface elevation decreases up to 1 foot in response to the restoration plan in the Fish and Wildlife Service Pine Creek Unit. The restoration plan for the Fish and Wildlife Service Pine Creek Unit incorporates a significant area of grassland and savannah, which have lower roughness coefficients than the orchard that was modeled in the existing condition. An overall reduction of approximately 0.5 feet is shown for much of the area upstream of Highway 32. This reduction is demonstrated graphically on **Figure 29**, which is a plot of the floodplain and water surface elevations immediately upstream of Highway 32.

A decrease in water surface elevation of between 0.5 to 1 feet occurs in the RX Ranch area. This decrease is due to the conversion of existing orchards to savannah, which has a lower roughness coefficient than orchard. The resulting decrease allows more flow south through the right-overbank (near RM 197) causing localized increases of approximately 1 foot within the Kaiser Unit, with smaller increases at the east limit of the model.

A check of the changes in freeboard along the east bank levee in the area of River Mile 193 shows that freeboard varies from 3.1 to 3.6 feet for the existing conditions and is reduced somewhat for the restoration scenario. Reduction in freeboard varies from 0.0 to 0.4 feet along this reach. **Figure 27** shows the profile of the top of the east levee at RM 193 and the two water surface profiles (existing and restoration conditions). **Figure 28** shows the field locations of the data points used in this profile.

4.3 Hamilton City Setback Levee Hydraulic Model

The resulting velocity contours and flow vectors for the setback levee model run are shown in **Figure 16**, the velocity differential is shown in **Figure 19**, the water depth plot is shown in **Figure 22**, and the water surface elevation differential is shown in **Figure 25**. There are some effects on velocity and water surface from the potential setback levee scenario, as shown in the figures. However, some of the changes are due to the presence of water in the area where the levee was setback (these areas were dry before the levee was set back).

The changes in velocity range from –3 feet per second to +3 feet per second, with the exception of a few areas. The velocity increases slightly in some of the east overbank areas, and greatly where the levee was setback. The increases associated with the setback levee cause a decrease in the channel velocity from RM 193 to 198. The velocity increases in the east floodplain are associated with the riparian restoration and explained in section 4.2. There is an increase of up to one foot in the channel between RM 198 and 199. The increase occurs because the new levee removes half of an abandoned oxbow from the floodplain, resulting in more flow moving through the channel.

Channel and floodplain deposition may be of some concern in three locations. Two of these locations are the result of the proposed riparian restoration and are discussed in the previous section. The third location is in the channel from RM 195 to RM 198. The velocities decrease from 1 to 3 feet per second in the channel. The most significant decrease is from 8.1 feet per second to 5.5 feet per second. Both of these velocities are sufficient enough to carry sediment, and therefore significant deposition is not expected.

The water surface elevation has significant changes due to the setback levee configuration. The water depth plot (Figure 21) shows up to 9 feet of water in the area of the setback. The areas where water was previously not permitted is easily noted in bright red on the water surface elevation plot (Figure 24) and the increase is not a cause for alarm. The largest water surface elevation change that is important to look at is located in the west overbank near RM 194, where there is up to 3.5 feet of an increase. The increase is due to the new proposed levee placed closer to the river, resulting in constricting of the flow. The constriction causes a resulting raise in the water surface elevation in the east overbank and up into Big Chico Creek. The new levee alignment also reduces the benefits of the riparian restoration in the RX Ranch.

The water surface decreases up to 4 feet in the far west overbank near RM 194. In the existing model, the levee did not extend this far, and the new levee restricts water from directly entering the area causing a reduction in water surface. A decrease in the water surface is shown in the area north of Hwy. 32. The reduction is due to a combination of the riparian restoration and setback levee. **Figure 29** shows the water surface elevation immediately upstream of Highway 32 for this alternative. The setback levee also reduces the rise in water surface elevation that the restoration caused in the Pine Creek Units.

A check of the changes in freeboard along the east bank levee in the area of River Mile 193 shows that freeboard varies from 3.1 to 3.6 feet for the existing conditions and is reduced to 1.8 to 3.5 for the setback levee scenario. Reduction in freeboard varies from 0.1 to 1.5 feet along this reach. **Figure 27** shows the profile of the top of the east levee and the two water surface profiles (existing and restoration conditions) and **Figure 28** shows the field locations of the data points used in this profile.

4.4 East Overbank Levee Removal Hydraulic Model

The results showing the velocity contours and flow vectors for the east levee removal scenario are shown in **Figure 17**, the velocity differential is shown in **Figure 20**, the water depth plot is shown in **Figure 23**, and the water surface elevation differential is shown in **Figure 26**. The east levee removal scenario has some minor effects on velocity and water surface, as shown in the figures. The majority of the effects shown on the figures are from the riparian restoration and the setback levee, which are incorporated into this model. Only the effects from the levee removal will be talked about in this section, the other changes are discussed in the two sections above.

The changes in velocity for the east levee removal are very similar to the changes for the set back levee with one exception. A small area near RM 198.5 shows that the increase in velocity from the riparian restoration is lessened from the removal of the levee. Channel and floodplain deposition is not expected from the removal of the private levees.

The water depth plot (Figure 22) shows that the water depth increases 10 feet where the levees use to stand, but this is because the levees were high ground before. The removal of the three levees allows more water to flow into the overbanks. This alternative provides some additional reduction in water surface elevation upstream of Highway 32 as shown on **Figure 29**.

A check of the changes in freeboard along the east bank levee in the area of River Mile 193 shows that freeboard varies from 3.1 to 3.6 feet for the existing conditions and is reduced to 1.8 to 3.5 for the setback levee scenario. Reduction in freeboard varies from 0.1 to 1.5 feet along this reach. **Figure 27** shows the profile of the top of the east levee and the two water surface profiles (existing and restoration conditions) and **Figure 28** shows the field locations of the data points used in this profile.

5. Conclusions

Based upon the results from the hydraulic modeling performed for this study, we offer the following conclusions for each of the modeled scenarios:

<u>Existing Conditions Hydraulic Model</u>

1. The computed water surface elevations from the calibration model compared within reasonable limits to the surveyed high water marks for the modeled storm runoff of January 1995.

2. For the purposes of this study, the existing conditions model is a reasonable representation of the velocities, water depths and flow patterns that would exist today for the given land use and a January 1995 flood event.

<u>Riparian Restoration Hydraulic Model</u>

1. The potential restoration scenarios provided by the TNC, decrease the water depth upstream of Highway 32 by approximately 0.5 feet. Within the Fish and Wildlife Service Pine Creek Unit, there are some reductions near the river as well as some increases in the interior areas where planting is denser.

2. There are localized increases within the Kaiser Unit of up to 1 foot and increases at the east edge of the model of 0.0 to 0.4 feet along the levee downstream from the Big Chico Creek confluence.

3. The changes in velocity are directly related to the change in density of the vegetation. Since maximum velocities in most floodplain areas are less than 5 feet per second, no significant increase in floodplain erosion is expected.

<u>Hamilton City Setback Levee Hydraulic Model</u>

1. The proposed setback levee reduces water surface elevations both in the river and in the floodplains upstream of RM 197.

2. There are increases in water surface elevation for the modeled storm condition from 0.5 feet to over 2 feet in the area of RM 192 to RM 195. This is due to the alignment encroaching into the west overbank floodplain in this area.

<u>East Overbank Levee Removal Hydraulic Model</u>

1. This alternative provides even further reduction in water surface upstream of Highway 32 for the modeled condition.

7. References

Ayres Associates, Sacramento River Bank Protection Project (SRBPP), Sacramento River and Tributaries. Hydrodynamic Modeling of the Sacramento River and Butte Basin from RM 174 to RM 194, Prepared for the U.S. Army Corps of Engineers, Sacramento District. December 1997

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U.S. Army, Corps of Engineers – Sacramento District, Sacramento & San Joaquin River Basins Comprehensive Study Initial Project, Hamilton City – Flood Damage Reduction and Ecosystem Restoration Feasibility Study, Hydraulic Design Document Report, 2001

U.S. Army, Corps of Engineers - Engineering Research and Development Center, RMA-2V Version 4.3 User's Manual, 1997

Appendix

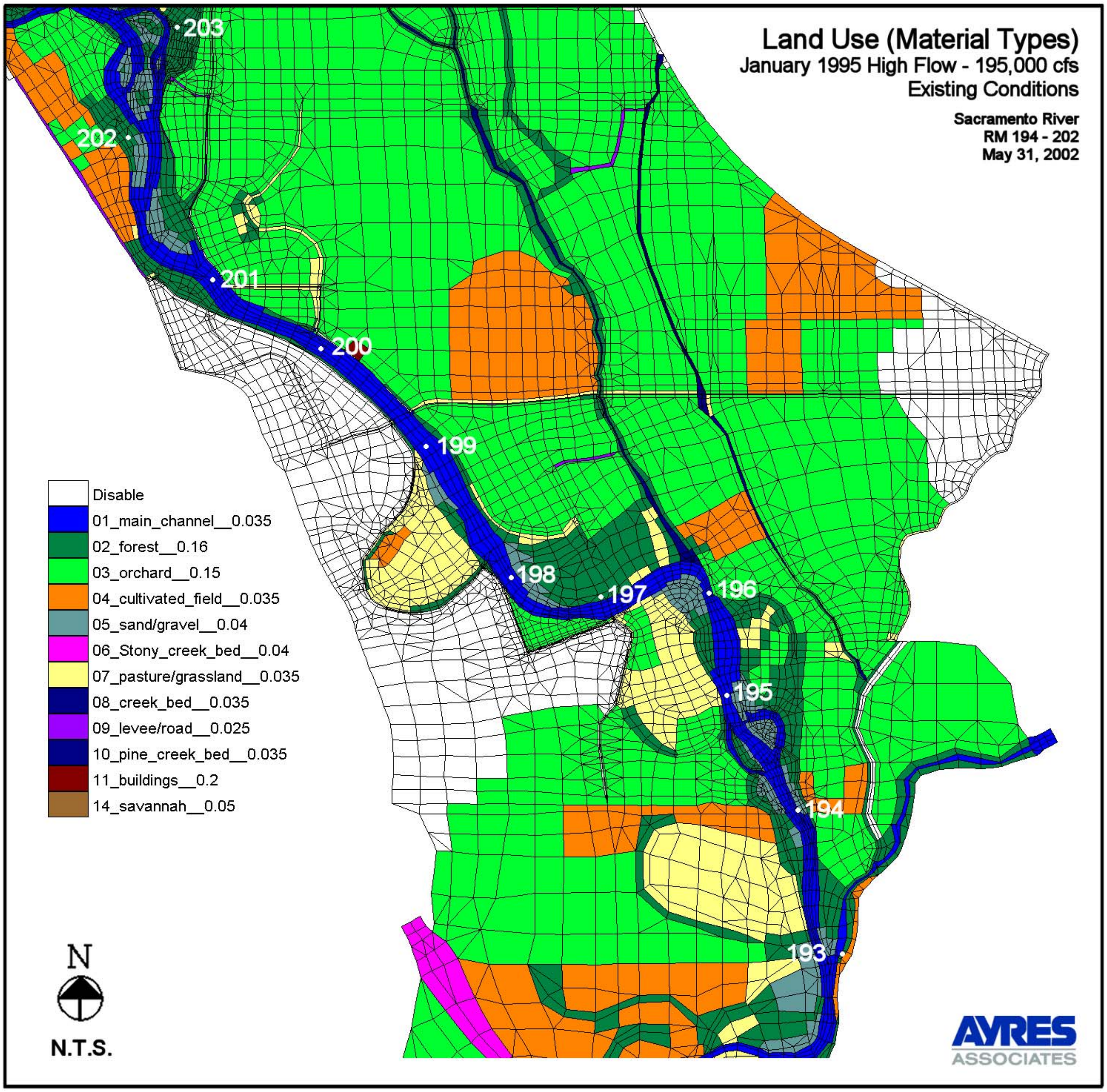

Figure 10. Land Use/Material Types - Existing Conditions

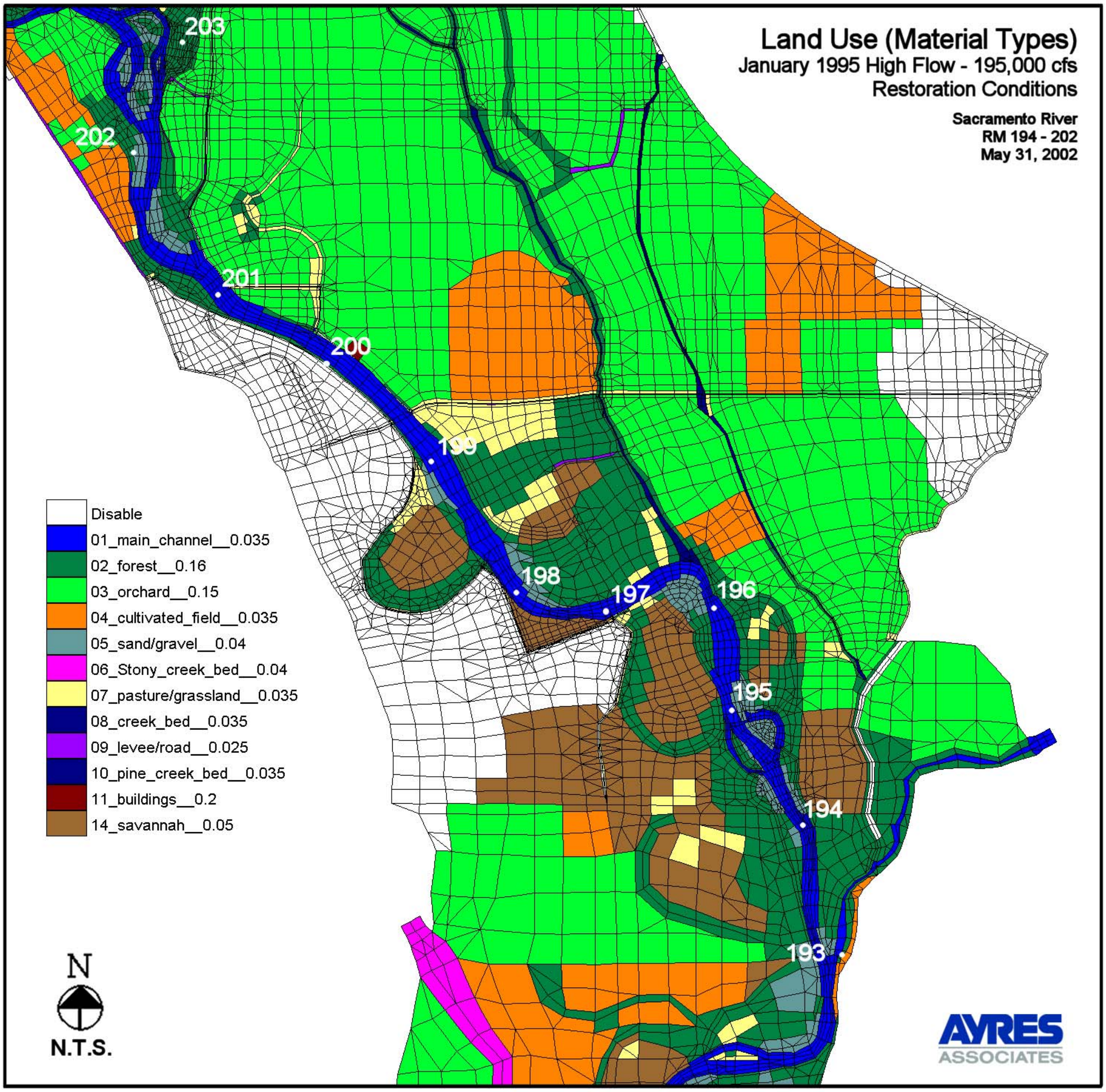

Figure 11. Land Use/Material Types - Restoration Conditions

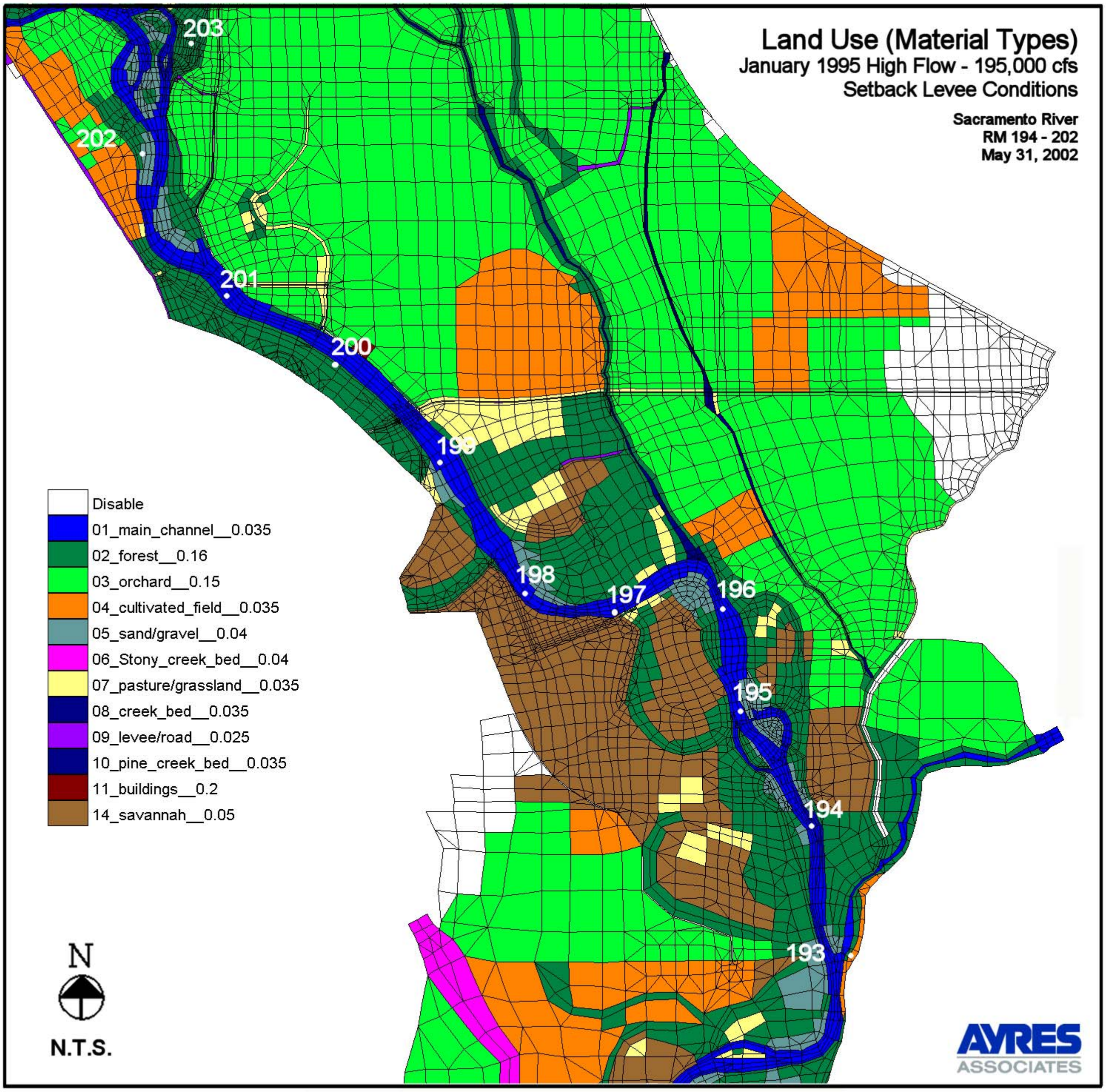

Figure 12. Land Use/Material Types - Setback Levee Conditions

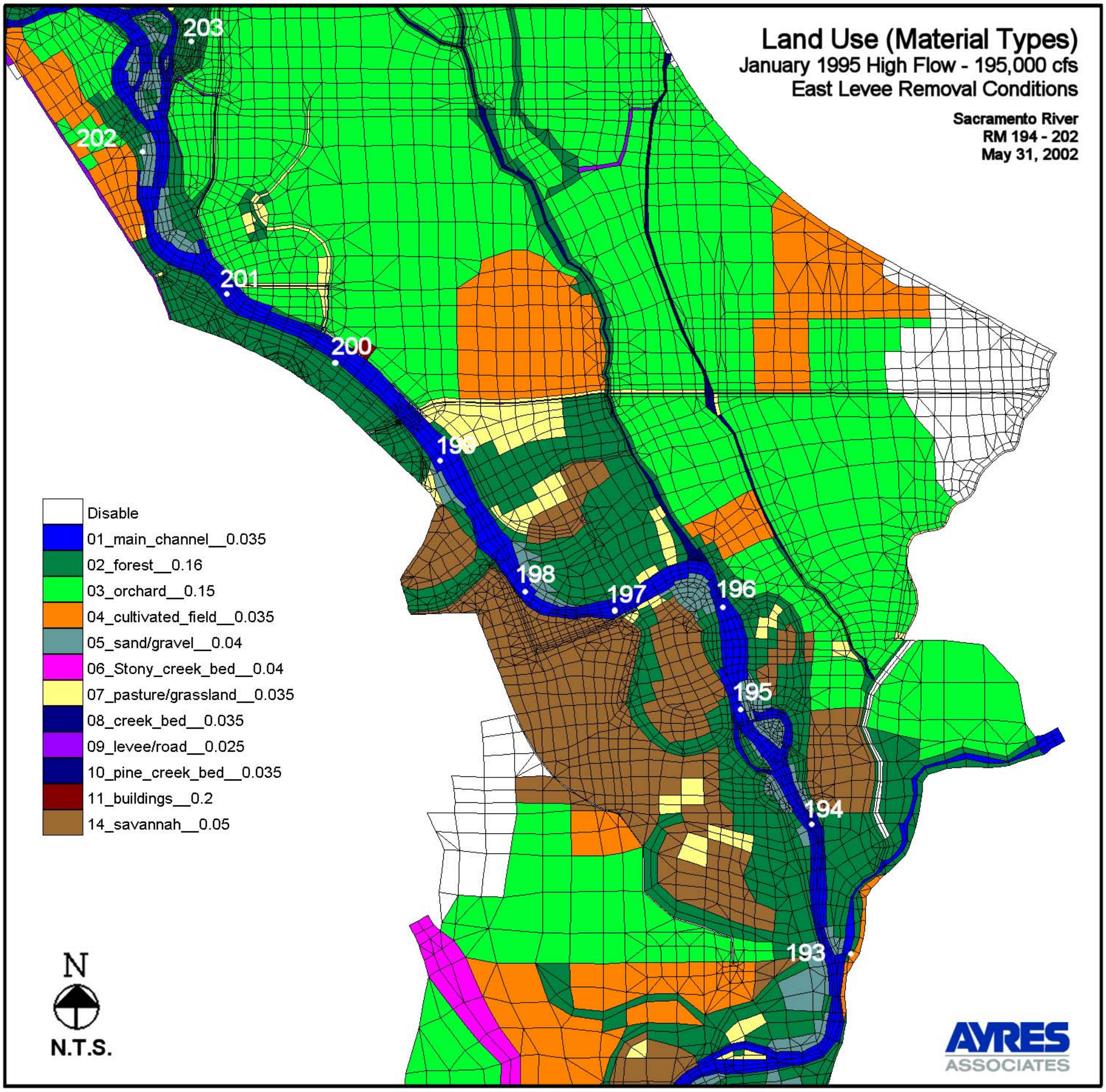

Figure 13. Land Use/Material Types - East Levee Removal Conditions

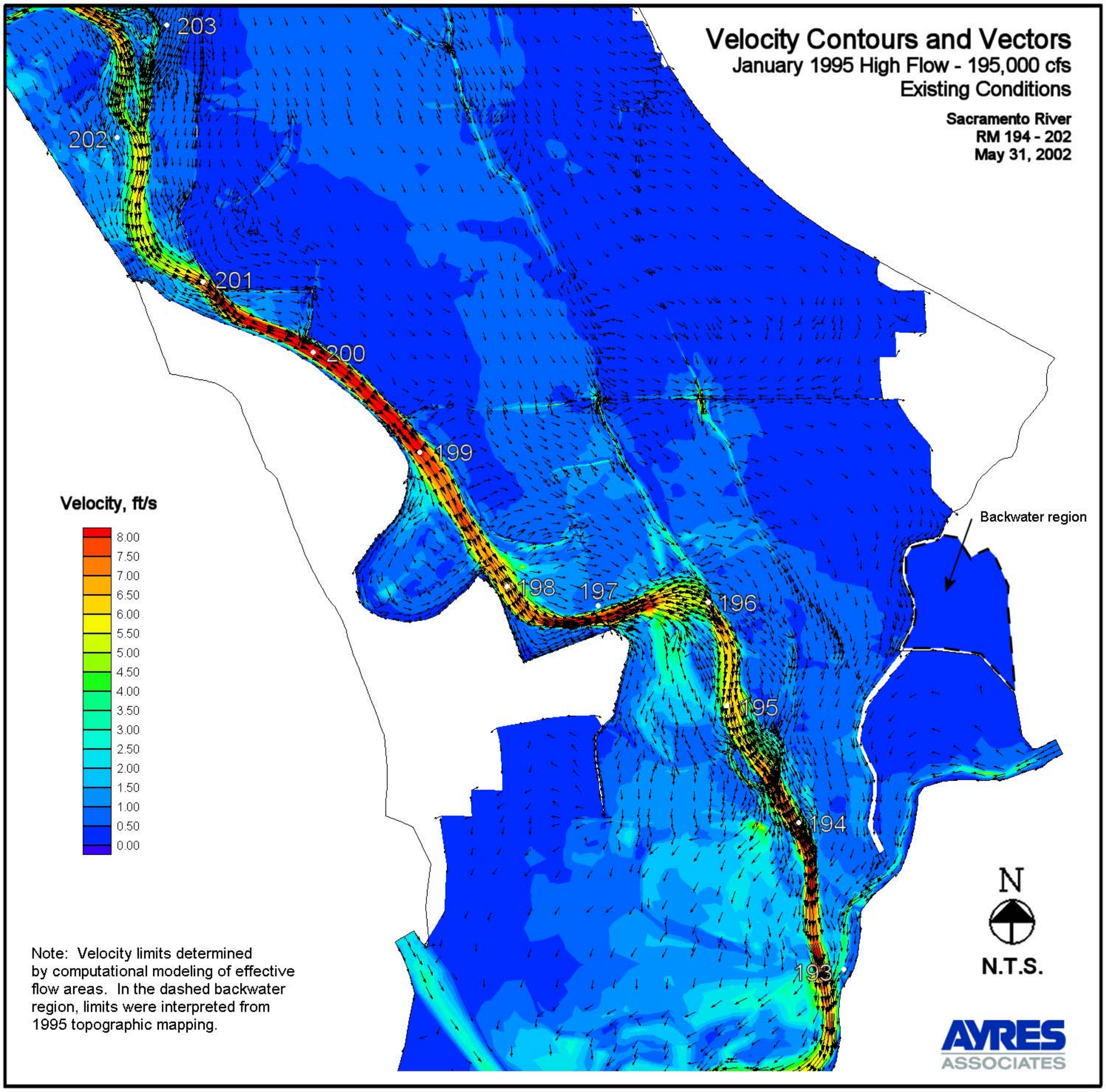

Figure 14. Velocity Contours and Vectors - Existing Conditions

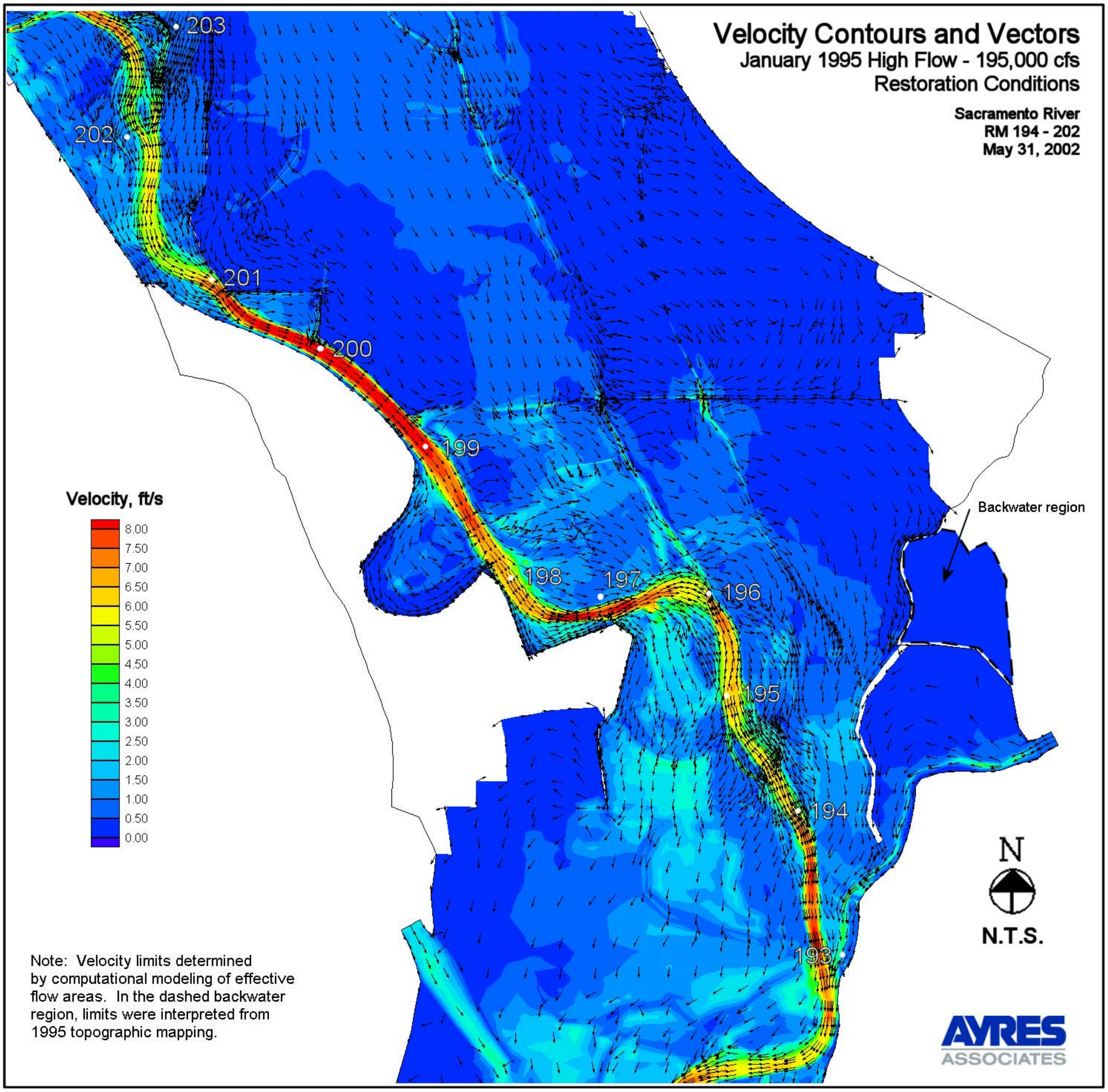

Figure 15. Velocity Contours and Vectors - Restoration Conditions

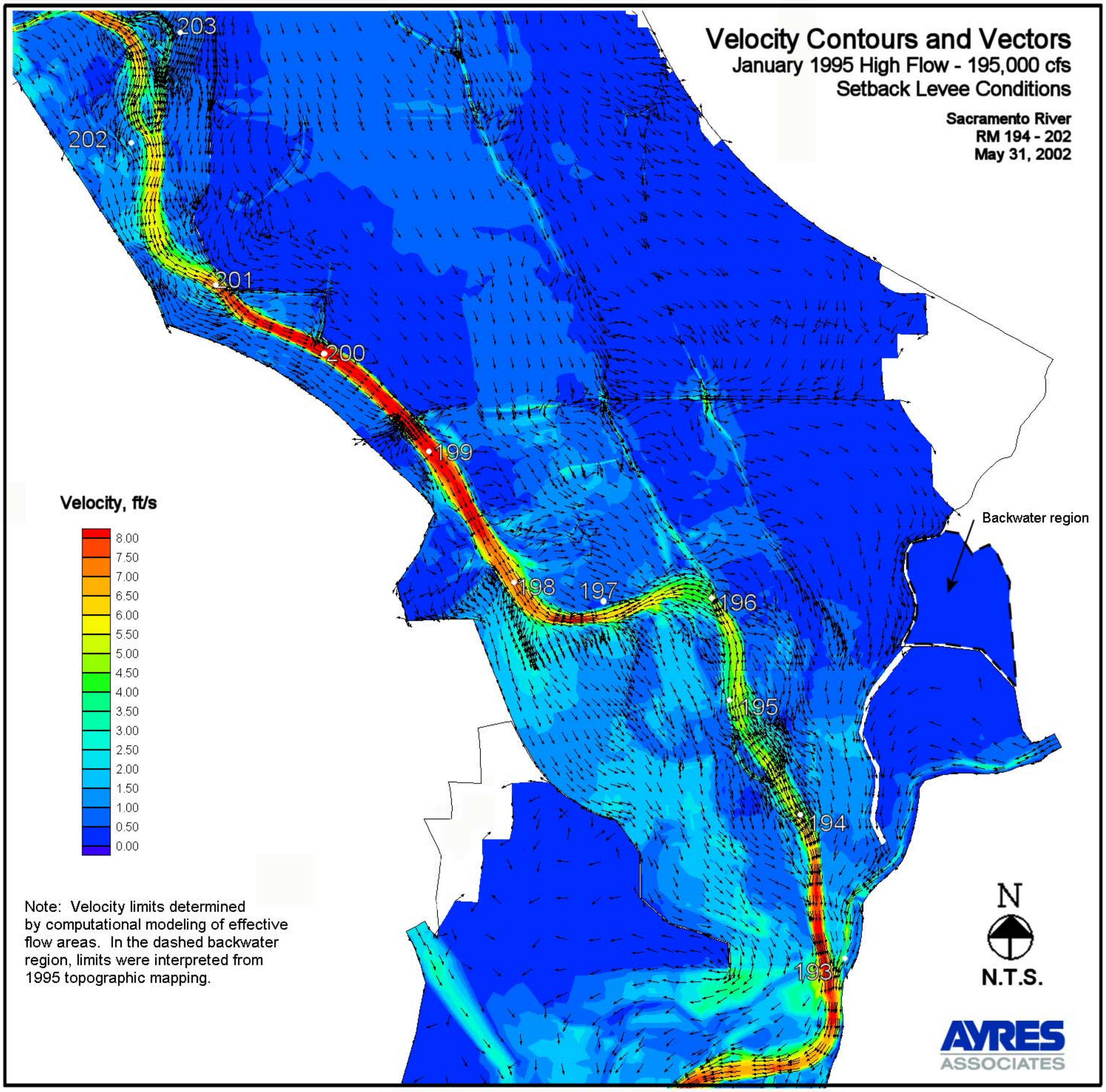

Figure 16. Velocity Contours and Vectors - Setback Levee Conditions

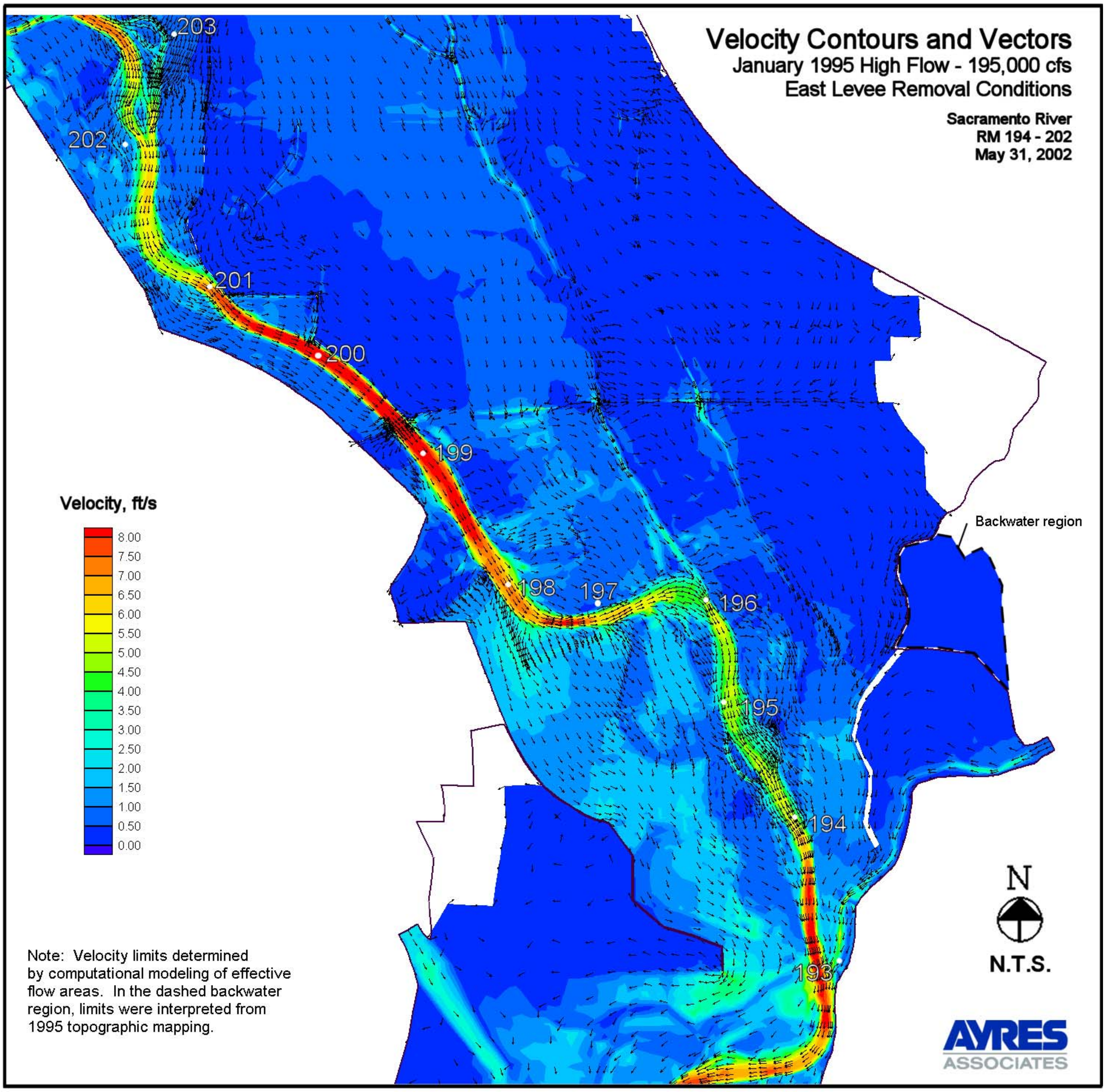

Figure 17. Velocity Contours and Vectors - East Levee Removal Conditions

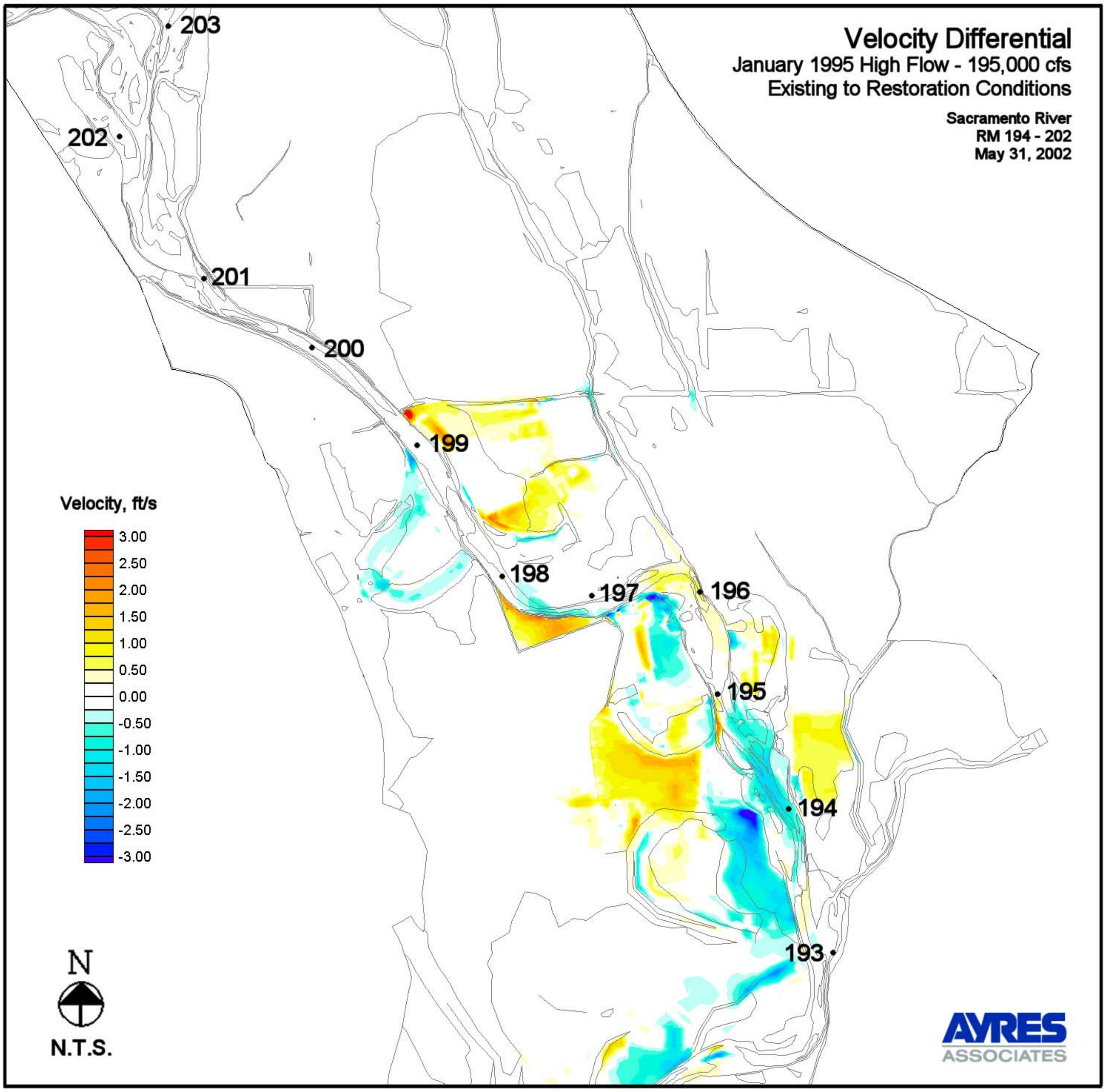

Figure 18. Velocity Differential - Existing to Restoration Conditions

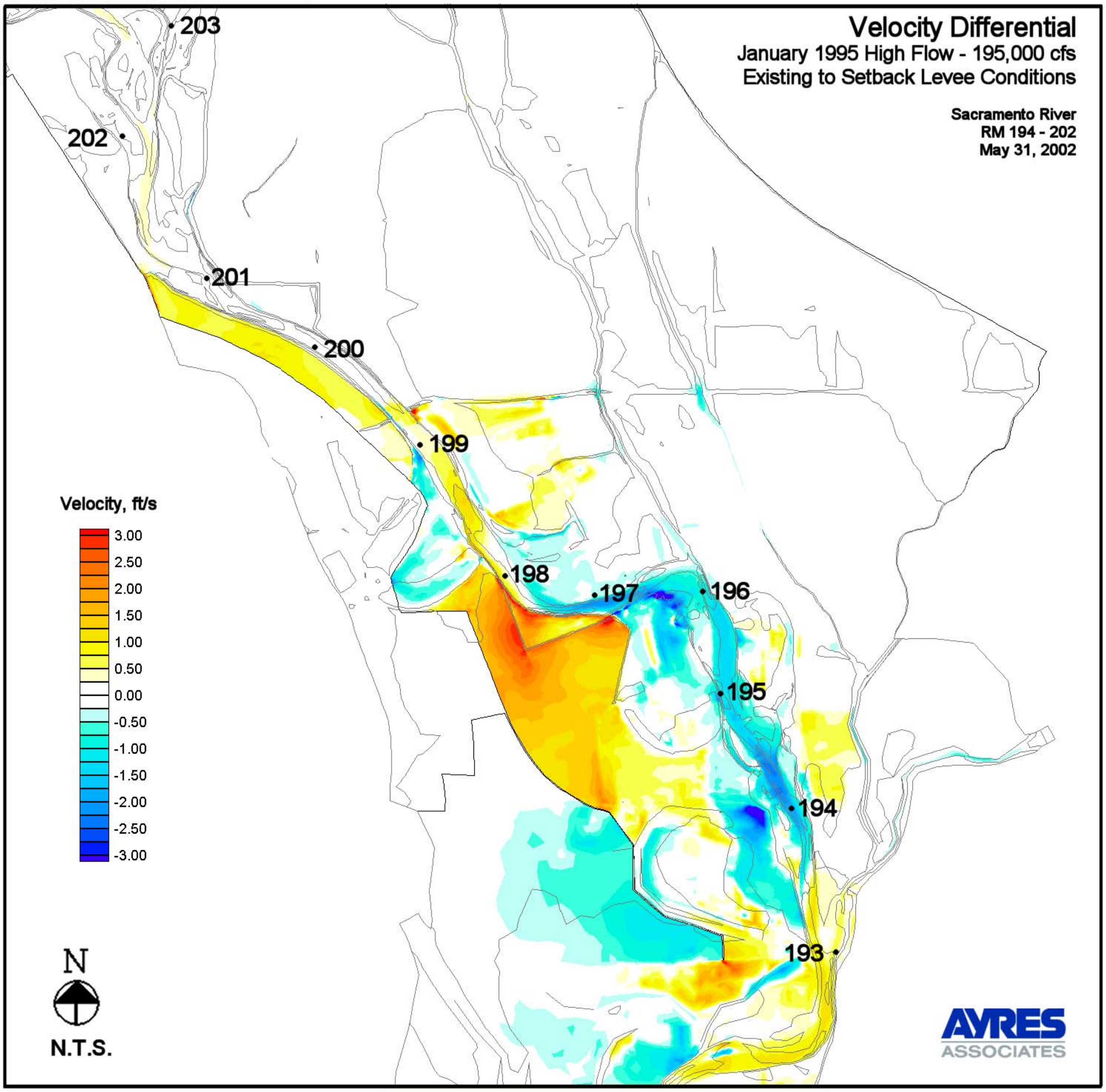

Figure 19. Velocity Diferential - Existing to Setback Levee Conditions

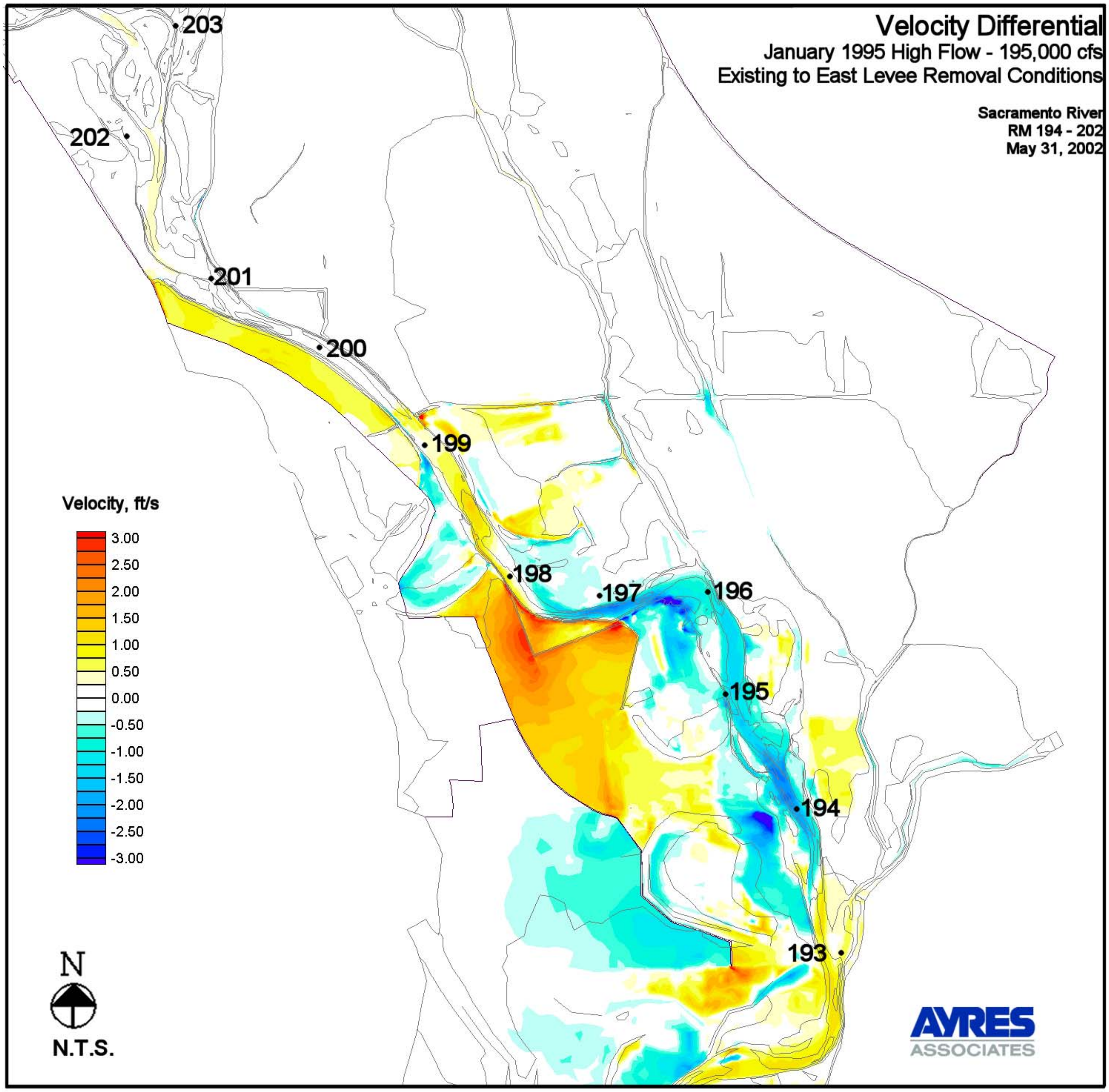

Figure 20. Velocity Diferential - Existing to East Levee Removal Conditions

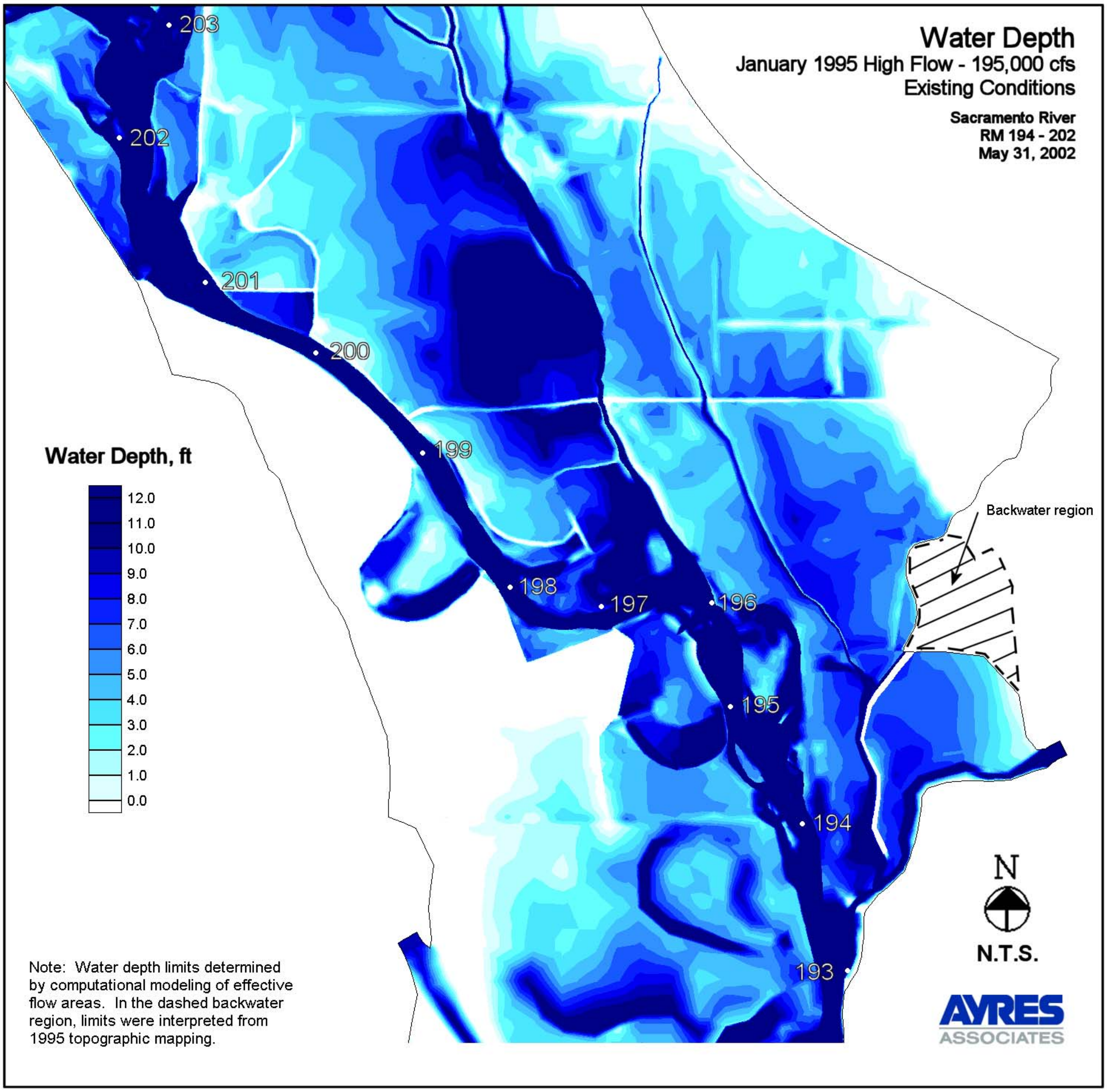

Figure 21. Water Depth - Existing Conditions

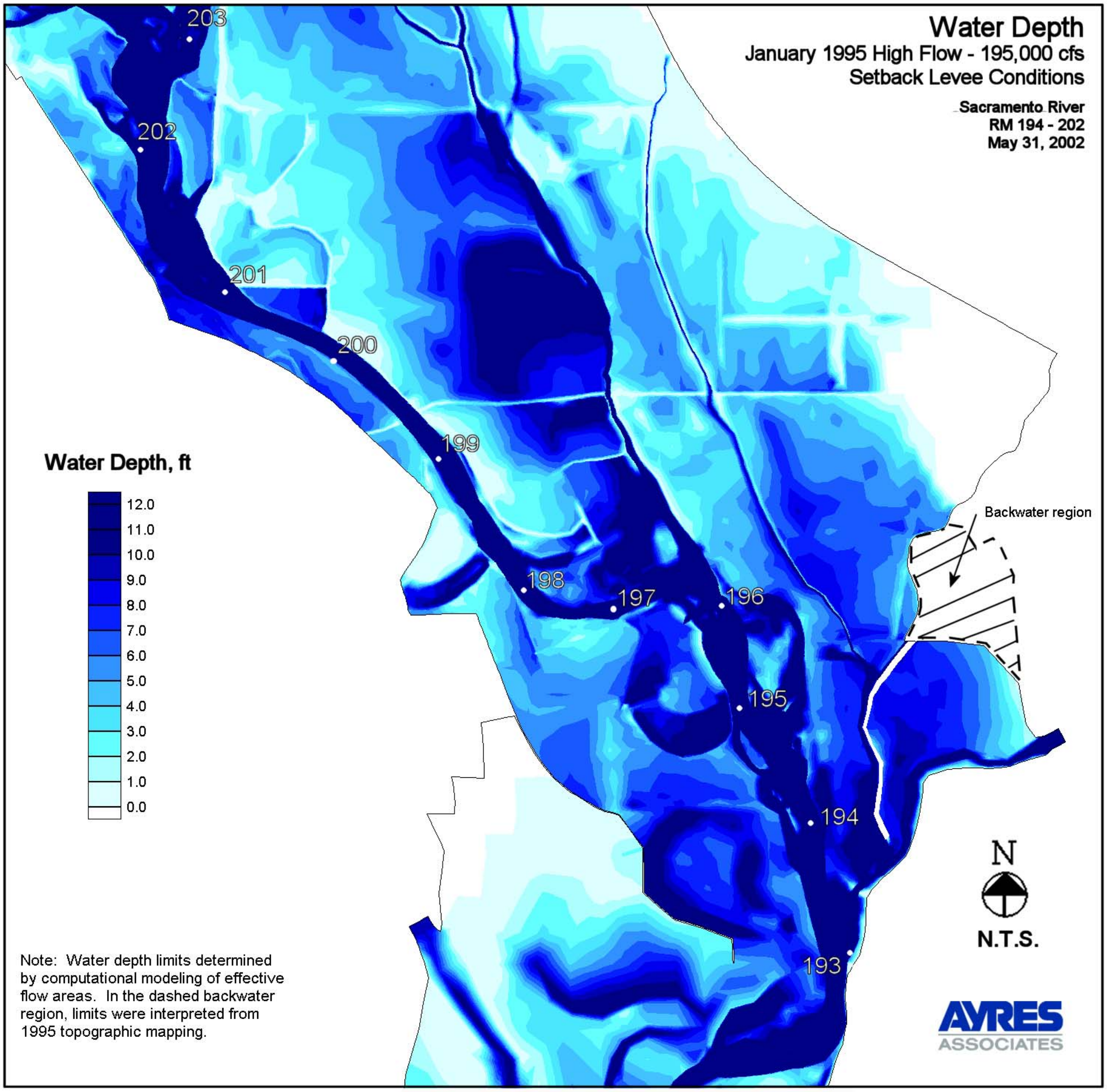

Figure 22. Water Depth - Setback Levee Conditions

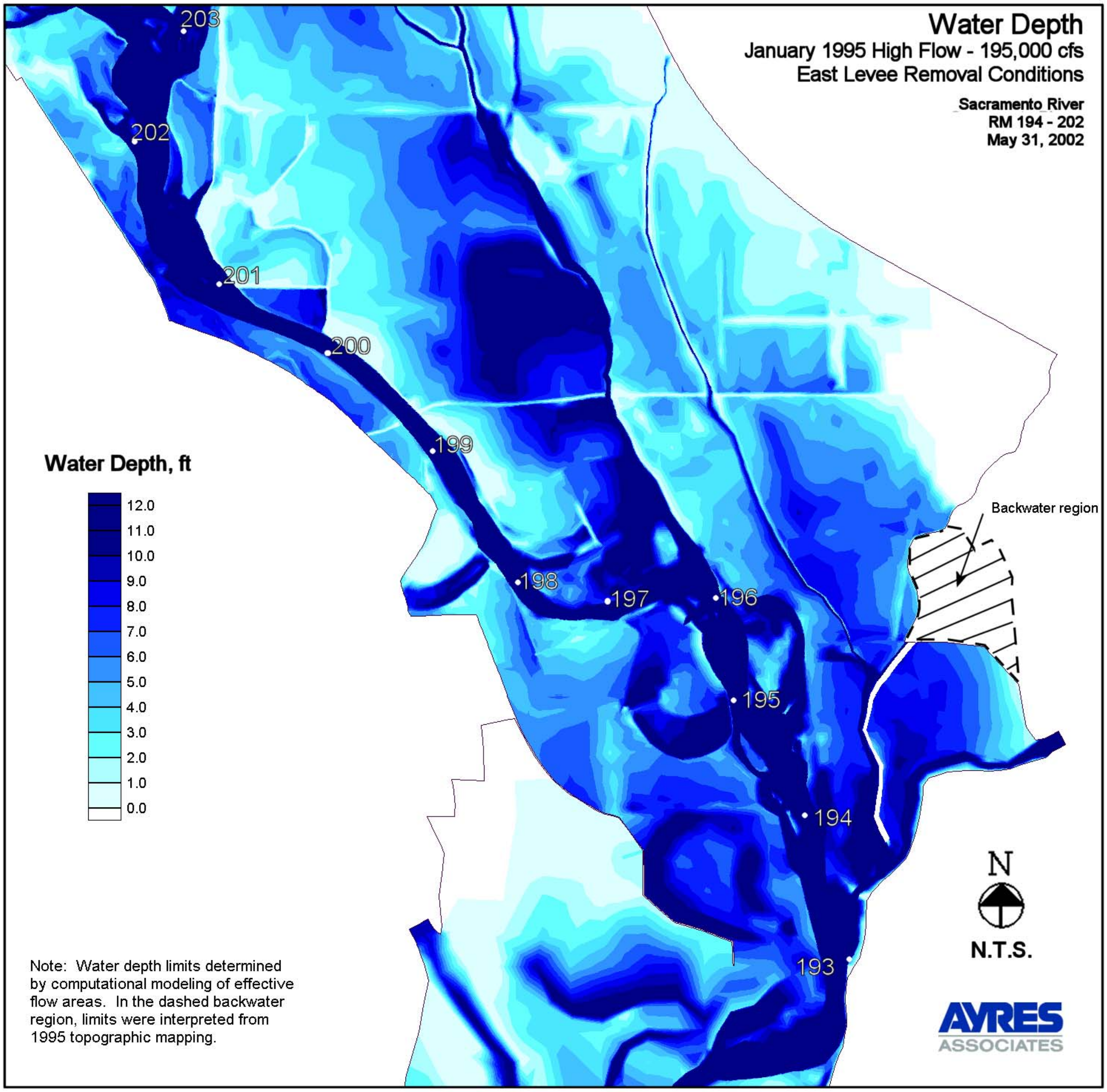

Figure 23. Water Depth - East Levee Removal Conditions

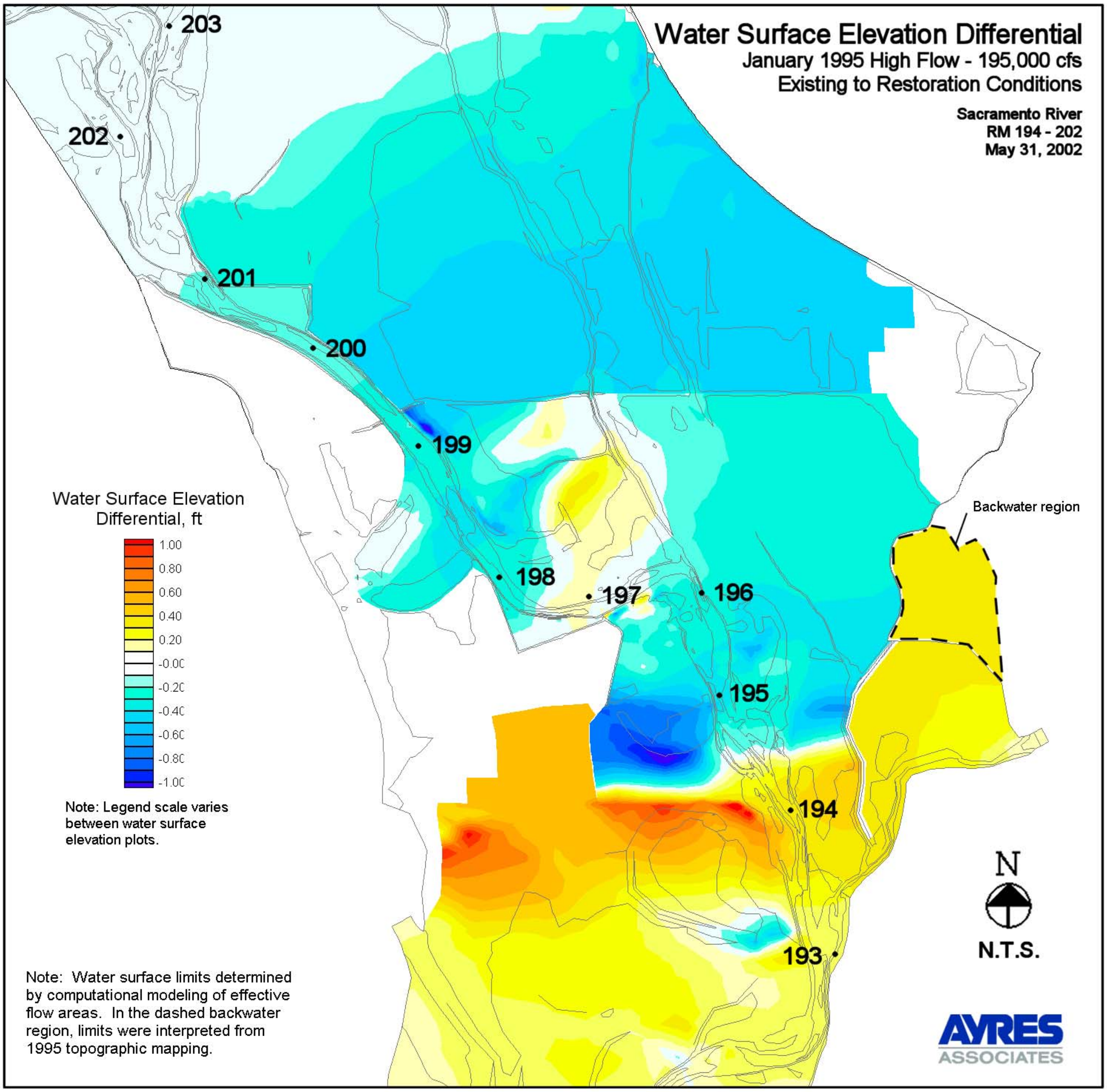

Figure 24. Water Surface Elevation Differential - Existing to Restoration Conditions

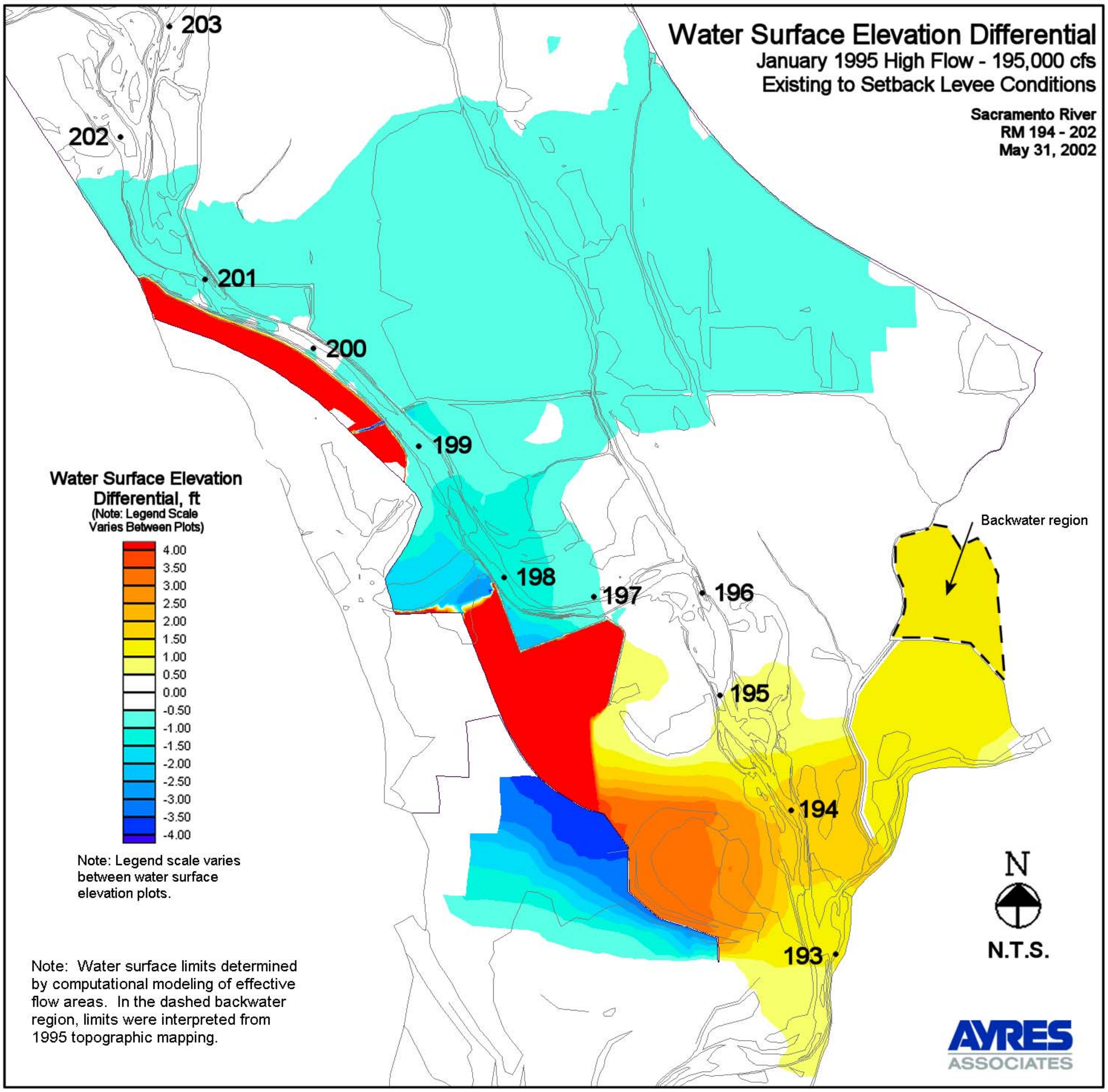

Figure 25. Water Surface Elevation Differential - Existing to Setback Levee Conditions

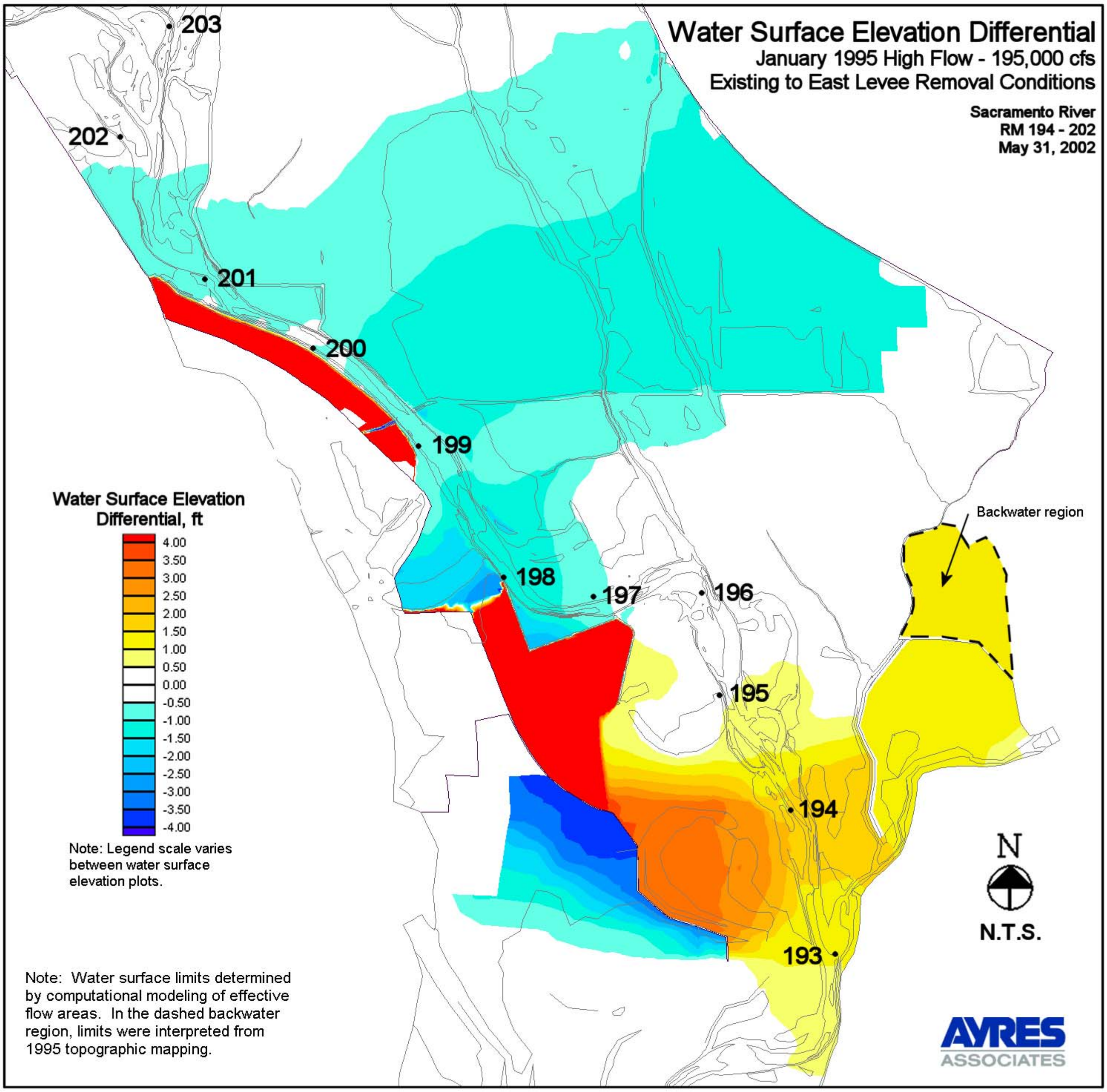

Figure 26. Water Surface Elevation Differential - Existing to East Levee Removal Conditions

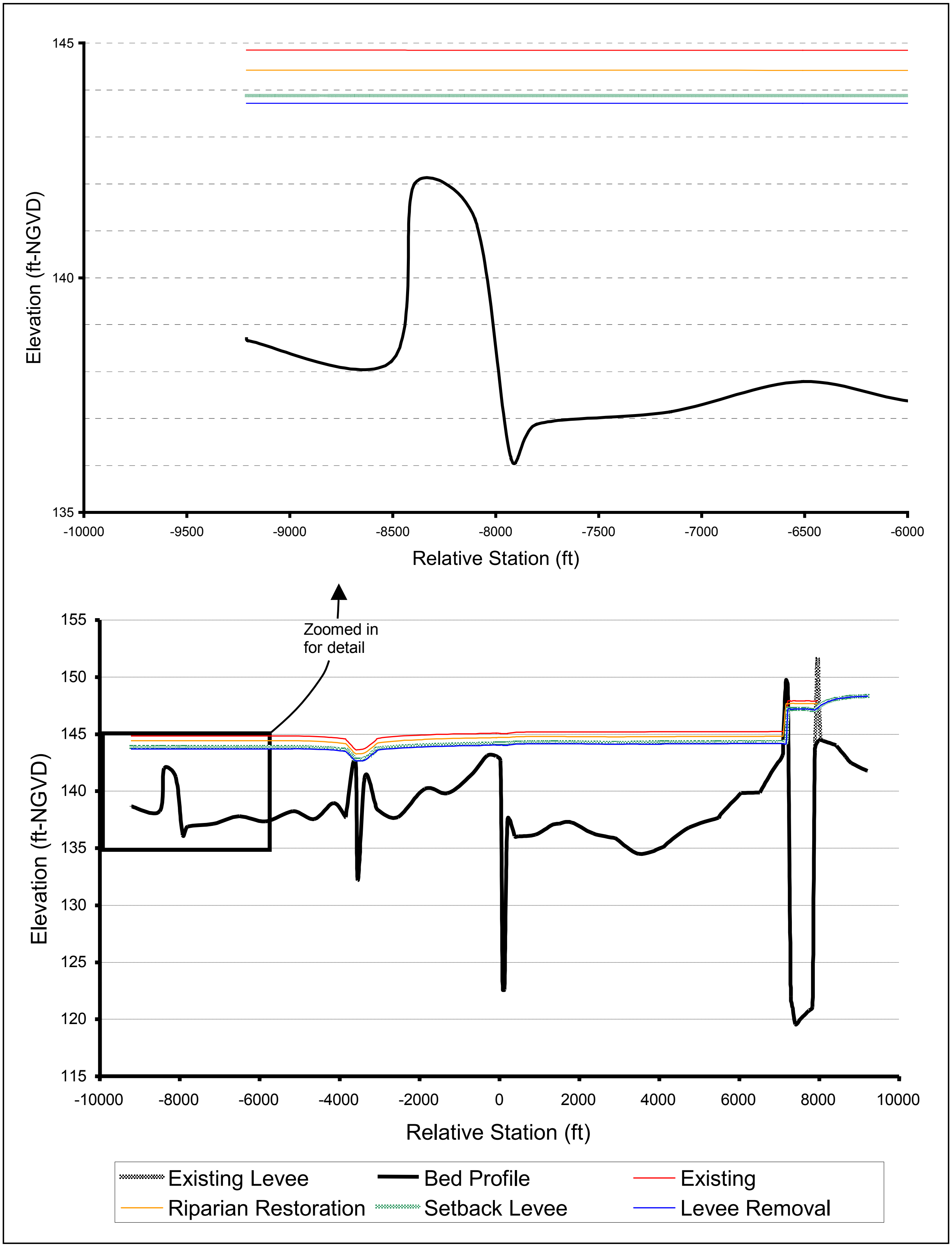

Figure 27. Computed Water Surface Elevations Upstream of Highway 32

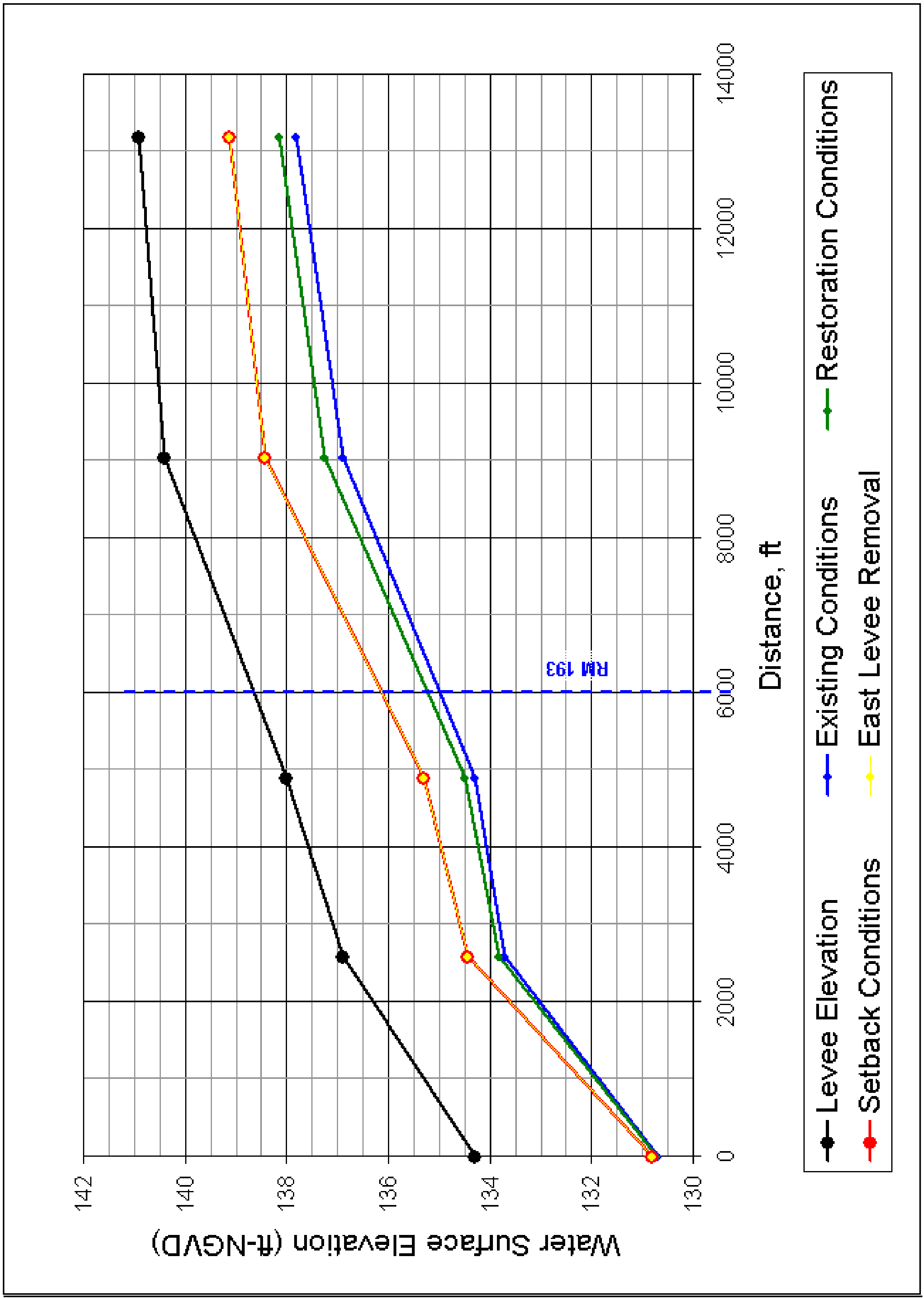

Figure 28. Levee Profile and Computed Water Surface Elevation Along East Levee at RM 193

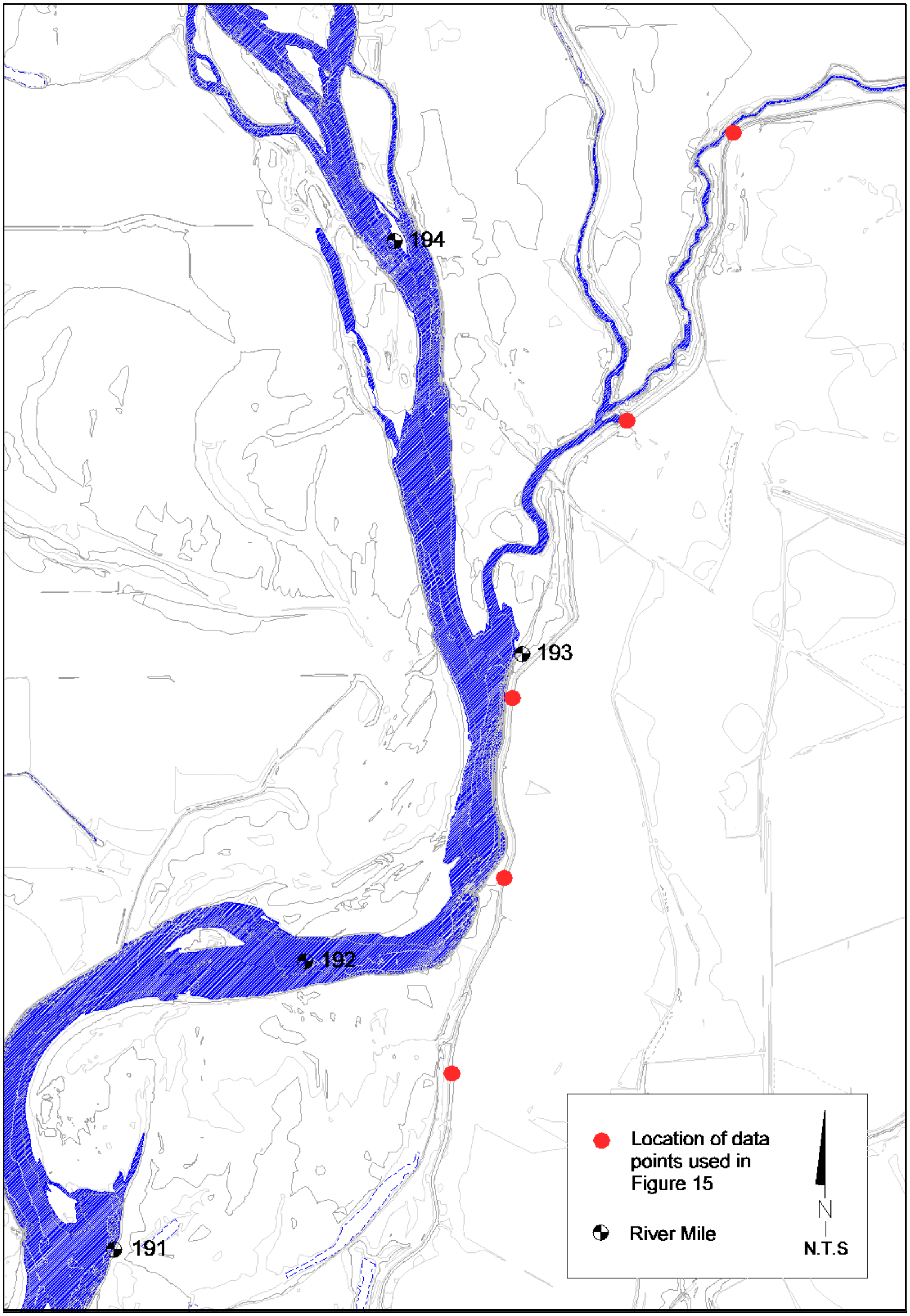

Figure 29. Plan View of East Levee Showing Data Point Locations